AN ANALYTIC STUDY ON SPHERE OF ELASTIC MATERIALS USED FOR FREEZING PAVEMENT

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1.ABSTRACT

When the surface of pavement covered with snow is frozen, it is dangerous for vehicles and walkers. There are many ways to restrain the surface freezing of pavement and break the freezing layer of it. The restraint ways contain melting methods by heat, peeling ways by clearing snow work and breaking freezing layer methods (it is call as breaking methods) by traffic loads and so on. The breaking methods contain of using elastic material constructed on the pavement surface. When vehicles pass on it, the freezing layer is broken by shear stress and bending stress produced by deflections of elastic materials. The breaking method needs the lowest maintenance cost of all restraint systems of freezing layers

One of the disadvantages of breaking methods is that the thicker is the freezing layer, the more difficult is it to break the layer by traffic loads. Now, it is hoped to examine the sphere of the methods.

To investigate this sphere, this study contains as follows.

[1] Deflections of elastic material in-situ in the peeling methods were measured by a portable FWD (Falling Weight Deflectometer) .
[2] Deflections for these methods were estimated by analytic methods
[3] The sphere of the peeling methods was estimated by the elastic analysis

3 types of breaking methods on asphalt pavements were adopted in this study. These were as follows.

1) A cylindrical rubber with a diameter of 75 mm had a thickness of 25mm.pasted on the pavement
2) A wasted tires rubber pasted on an inter-rocking block that is called IL block.
3) A grooving method with urethane material situated on the pavement

From the examination of this study, it is concluded that breaking methods have effect on freezing layer thickness of under 50 mm that depend on wheel loads.

2. INTRODUCTION

The materials for restraining the surface freezing of pavements have been proposed in the cold region of Japan. But it has been a few studies for the sphere of these materials. And most of these materials are studied for winter season but it is necessary to study the durability throughout annual surface change in temperature and speed of vehicles and so on.

In this study, the sphere of these materials is examined by considering the elasticity using portable FWDs and material annual durability is studied by the displacements using the measurement device. The falling weight deflectometer (FWD) is known as the equipment for measuring the load and deflection that are generated by the impact of a dropped weight. And the portable FWD has been developed as the same measurement system as FWD (see Fig.1). A portable FWD weighs merely 15kg and therefore the load and deflection measurements can be made at the any point inaccessible to vehicles. The table 1 showed a portable FWD.

Table1 Outline of a portable FWD

Dia.of loading plate (mm)	90,200,300
Falling Weight (kg)	5,8,10 15
Falling Height (mm)	50 - 380
Max.Deflection (mm)	2.0

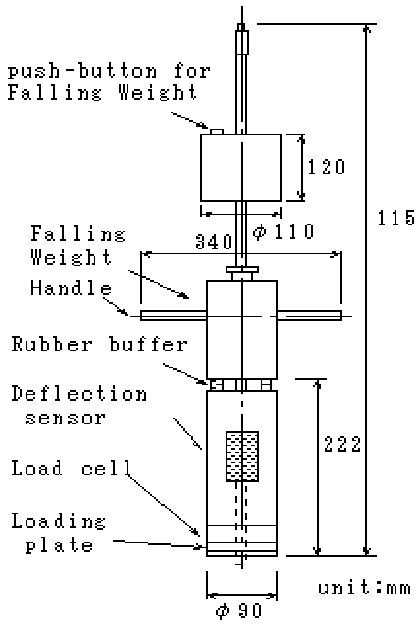

Fig.1 Portable FWD

3. CYLINDRICAL RUBBER

3.1 *Material*

A cylindrical rubber with a diameter of 75 mm and the thickness of 21mm is embedded and pasted on the asphalt pavement. . The adhesive consists of epoxy bonding. The height, which protrudes from the surface, is less than 3mm(**Fig.2**). This material exceeds 160 N/mm in tensile strength. As the standard, the interval of the rubber material is from 150mm to 200mm.

When the rubber shrinks at the weight of the cars and trucks that pass on the rubber, the snow and ice layer bend and the destruction of the layer is generated under the condition that the layer of the snow and ice is thin. This material is introduced in the Sapporo City 1996, and it is being constructed mainly on pedestrian crossings.

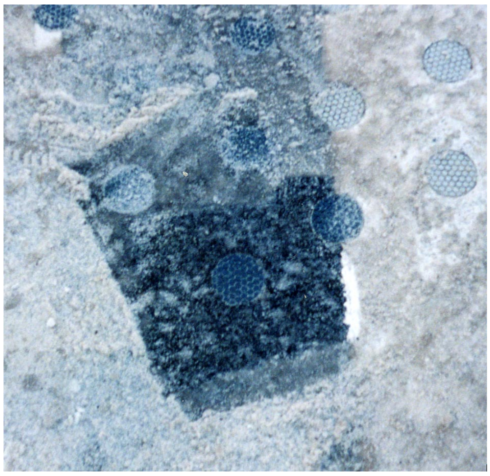

Fig.2 Cylindrical Rubber

3.2 *Sphere of this material*

With the survey result of the peeling effect of the snow and ice, it is appeared that this material was not effective in the thickness of 200mm and the effect appeared at about 100mm thickness. In 100mm thickness or less, this effect is sufficiently demonstrated**.**

In order to clarify this phenomenon, the difference in the elasticity between asphalt pavement and the rubber material was examined as follows. By setting the impact forces at 4 stages (3,5,7,9kN), deflections of asphalt pavement and a cylindrical rubber were measured using a portable FWD under the freezing condition of the pavement (**Fig.3**). The temperature of the surface was almost -3 degrees C.

Fig.4 is shown in the relationship between deflection and impact force in a cylindrical

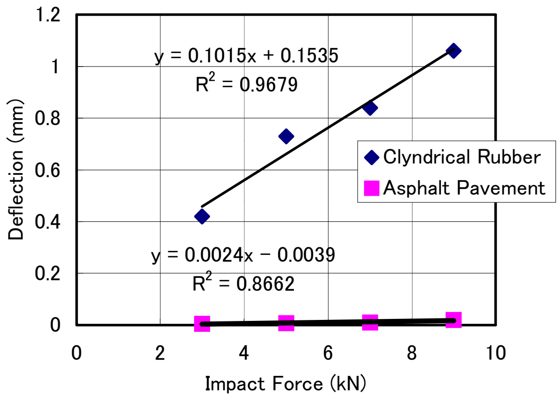

Fig.3 Measurement in the freezing condition

Fig.4 Measurement of cylindrical rubber and asphalt pavement.

rubber and asphalt pavement. It is shown in this figure that the deflection is proportional to the load in the cylindrical rubber as the correlation coefficient R is 0.98. It is also true even in asphalt pavement as the correlation coefficient R is 0.93.

It is reported the compressibility factor of the ice is about 4kN.at 0 degree C [1]. And deflection of ice using this portable FWD is almost as large as asphalt in the condition that the impact load is 9kN and the depth of ice is 5omm at 0 degree C.

From the **fig.4,** it is proven that the displacements of the cylindrical rubber are 50 times as much as or more than those of asphalt pavement and ice. It has been reported from observations that the ice on these rubbers exfoliates on the round shape under traffic loads. It is supposed that the shear strength of the wheel load is larger than that of the ice, because the deflection of the rubber is far bigger than that of the ice from this **fig. 4**.

The elucidation as following was tried on the basis of the conventional research results in respect of this phenomenon. The following equation is proposed the relationship between wheel load (**P**: kN) and grounding radius (**a**) (r: mm) of the tire of the automobile[2].

$$\mathbf{a} = \mathbf{P} + \mathbf{120} \qquad (1)$$

The ice shear resistance force (**Q**) for the wheel load is estimated the equation 2,as the shear stress of the ice is defined as **s** (kPa) and the depth of the ice is **d** (mm). And the radius of ice exfoliated is made to be **r** (mm).

$$\mathbf{Q} = \mathbf{s}\, 2\pi\, \mathbf{rd} \qquad (2)$$

The shear force (**F**: kN) of the ice by wheel load is shown in the following equation

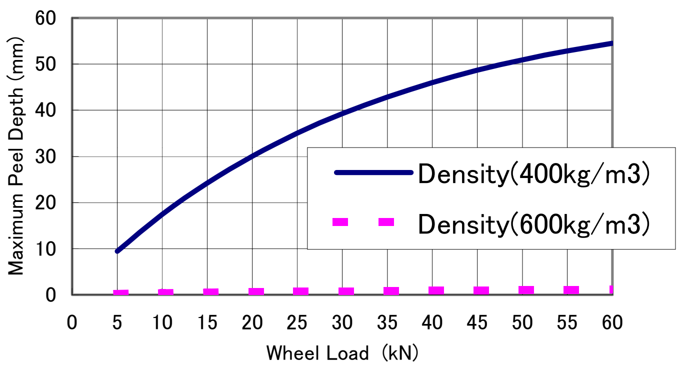

Fig.5 Maximum peeling depth (cylindrical rubber pavement)

$$\mathbf{F} = P\left(\frac{r}{a}\right)^2 \qquad \textbf{(3)}$$

Now, It has already been reported that the shear stress of the ice (**s**) is 20 kPa for the density 400kg/cm^3 and 1MPa for the density 600kg/cm^3.at the temperature –0 degree C or -10 degree C. It can be said that the ice. The peeling of the ice will be generated, when **F** is bigger than **Q**. As the sphere of this material, **Fig.5** shows the limit in which the peeling of the ice is generated. It can be said by this figure that this cylindrical rubber pavement is more effective under 50mm depth of snow ice layer as it is assumed that the maximum of usual wheel load is 50kN.

4. WASTED TIRE RUBBER PASTED ON AN INTER-ROCKING BLOCK

4.1 *Material*

It is advantageous that the rubber pavement can ensure anti-freezing surface, because the snow does not adhere to the surface. However, the skid resistance decreases with that the drainage of the surface is bad and it is difficult that the rubber is made to adhere to the block, because the telescopic motion of rubber is far bigger than that of concrete. The stud-less tire covers its surface with the flexible rubber notched that improves the drainage. And there is another advantage in the stud-less tire, that is, steel wire is included in it that is able to suppress the telescopic motion of the inside and the adhesion of the surface of the concrete is improved.
Then, wasted rubber of stud-less tire is adopted and is cut. It is stuck on the surface of generally used IL block. (This wasted tire rubber pasted on an inter-rocking block is called as a rubber IL block) The figure is shown in **table 1**.

Table 1 Figure of A wasted tire rubber pasted on an inter-rocking block (mm)

Inter-rocking block			Wasted rubber of stud-less tire	
Length	Width	Height	Thickness	Depth of notch
195	95	60	13	5

4.2 *Sphere of this material*

The general IL blocks and the rubber IL blocks were constructed alternately shown in **Fig.6**.One of the reasons why they were constructed alternately is the promotion of the ice peeling by hard layer and soft layer on the surface of block pavement. Another reason is the protection from the blade for the snow clearing.

Fig.6 general IL blocks and the rubber IL blocks

In the block paving, it is important to transmit the load from one block to another. The following formula was adopted in order to examine the degree of the load transfer.

$$R = \frac{2d_{12}}{(d_0 + d_{12})} \times 100 \qquad \textbf{(4)}$$

Where:

R : Load transfer ratio (%) d_0 : Deflection right under loading point (mm)
d_{12} : Deflection at 12 cm distance from the loading point (mm)

The values of load transfer ratio were estimated using a portable FWD. The deflection sensor installed in this main body measured the values of d_0. (This sensor is called as d_0 sensor). Another senor of which the transfer is possible measured the values of $d_{12.}$ (This sensor is called as d_{12} sensor). **Fig.7** shows the data of this block pavement that had been constructed for 3 years. Each value of load transfer ratio is presented in this figure where d_0 sensor was set on the general IL block and d_{12} sensor was set on the rubber IL block. In general, the values of load transfer ratio are more than 70% in good condition of the IL block pavement. Then, it can be said that this IL block pavement is almost good condition from the values of load transfer ratio in **Fig.7**.

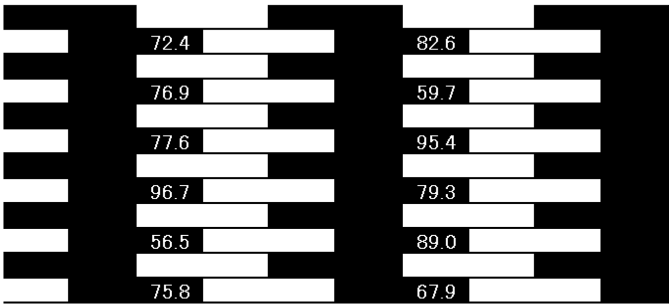

Fig.7 Load transfer ratio

Fig.8 shows that the peeling state of the ice of this rubber IL block pavement. The depth of ice layer was about 20or30 mm and ice layer was peeled on the rubber IL blocks. It was reported that the rubber IL blocks was more effective by the grooving of the surface to peel the surface ice layer water[3].

Fig,8 Peeling state of the ice

The method for analyzing in 3 chapters was used to estimate the sphere of this material using theoretical method. The grounding radius (**a**) (r: mm) of the tire of the automobile was required by the formula (1). By the estimation of load transfer ratio, this IL block pavement could be considered as a continuum. The theoretical model was adopted such as the ice layer on the rubber was peeled by the bending stress by wheel load. The bending stress strength was assumed 2.5MPa at the temperature –0 degree C or-10 degree C[4].

Fig.9 is presented that the relationship between maximum peeling and wheel load. It can be said by this . figure that this rubber IL block pavement is more effective under 25mm depth of ice layer as it is assumed that the maximum of usual wheel load is 50kN.

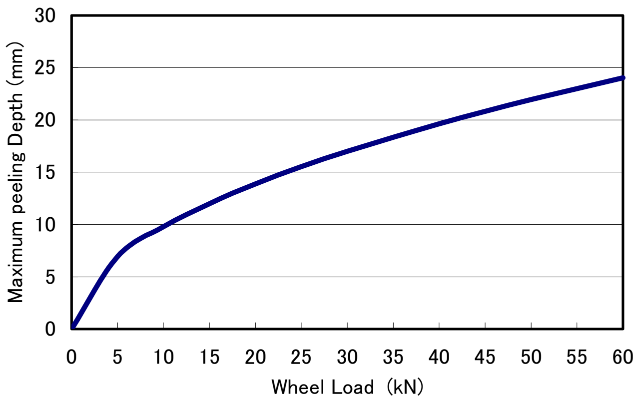

Fig.9 Maximum peeling depth (rubber IL block)

5. GROOVING ASPHALT PAVEMENT

5.1 *Material*

The grooving pavement is constructed cutting the groove in the pavement surface and filled the urethane in it. The depth of the groove is 10mm and the width of the groove at 6mm.And the interval in the groove is 40mm. **Fig.10** shows the condition that the snow and ice has been peeled in the grooving pavement.

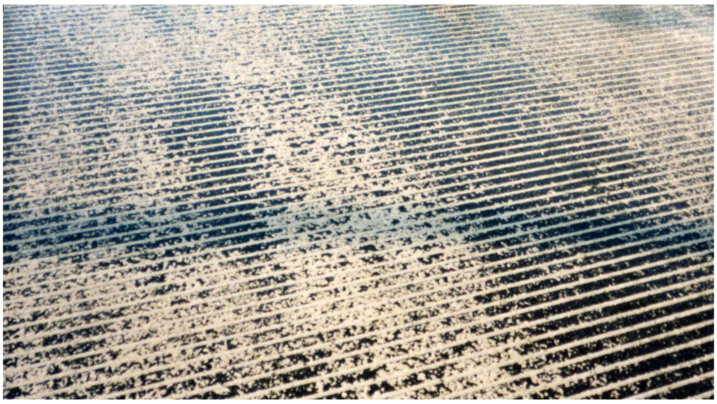

Fig.10 Snow and Ice peeled in the grooving pavement.

5.2 *Sphere of this material*

The deflections of the grooving pavement and the standard asphalt pavement were examined to study the bending of an ice layer follows bending of the whole pavement under wheel loads. **Fig11** shows the measurement situation by a portable FWD equipment. One of the deflection measurement results is presented in **Fig.12** in the grooving and the standard asphalt pavement loaded by 50 kN. It accepts that deflection of the grooving pavement is large about 1.6 times compared with the standard pavement under loading point. In the state where ice adhered on the grooving, a back-calculation method was introduced to examine the minimum bending stress under the wheel loads that peeled the ice layer. Some of the important results are as follows: The bending stress strength of ice layer is assumed 2.5MPa at the temperature –0 degree C or-10 degree C[4]. In these annalistic results, the bending stress in the bottom of the layer is estimated 0.4MPa in 50mm of thickness of the ice layer and that stress is also estimated as o.9Mpa in 10mm. Therefore, in practice, it can be regarded that the bending stress of ice layer was not so large for peeling.

Fig11 Measurement by a portable FWD

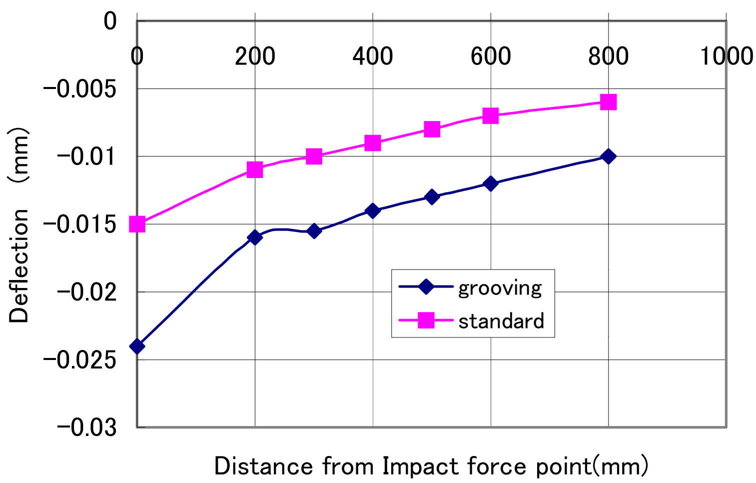

Fig.12 Deflection of grooving and standard pavement

As the next study, the peeling of the ice was examined by the attention to the shear force by the similar method used in the cylindrical rubber. The stress analysis in the grooving asphalt of which width was 6mm deferred from that in the cylindrical rubber of which diameter was 73mm, that is, the former was using the whole grounding area of a tire and the latter was using one cylindrical rubber block. **Fig.13** presents the sphere of this material (the density is 400kg/m^3).

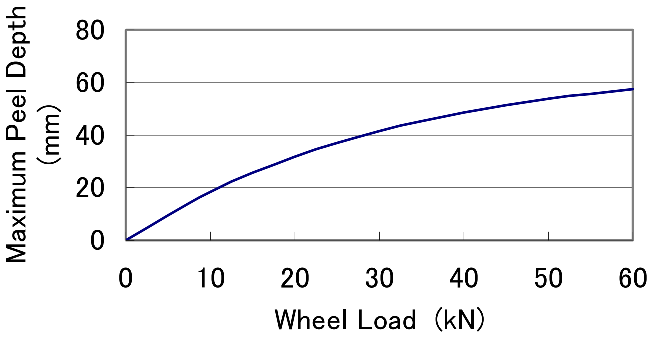

Fig.13 Maximum peeling depth (density: 400kg/m^3) (the grooving asphalt)

Then, it could be said the maximum peeling depth is about 50mm for the 50 kN wheel load.

6.CONCLISION

Deflections of elastic material in-situ in the peeling methods were measured by a portable FWD and were estimated by analytic methods. Then, each sphere of the breaking methods was estimated by the elastic analysis 3 types of peeling methods on asphalt pavements were adopted in this study. The values of more effective depth of snow ice layer for peeling as it is assumed that the maximum of usual wheel load is 50kN were as follows.

1) The cylindrical rubber pavement is under 50mm
2) The rubber IL block under 25mm .
3) The grooving asphalt pavement is 50mm

7.REFFERECES

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