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THE STUDY ON ABRATIVE DAMAGES TO CONCRETE BRIDGE PIER BY RIVER ICE MOVEMENT AND PREVENTIVE METHODS OF THEM

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1. INTRODUCTION

Figure 1 shows damaged bridge piers by ice movement. Table 1 shows the damages on concrete bridge piers by ice movement in rivers in Hokkaido. Most of damaged piers are located in Okhotuk sea coast, where river surfaces are frozen up in winter. The result of investigation of the damages are summarized as follows:

(1) Damages are seen in the level of water, which suggests that damages are caused by river ice movement.
(2) The damage is the largest in the upstream side of the pier.
(3) Maximum thickness of the river ice in winter is 30 - 50 cm.
(4) Annual rate of the damage is estimated as 1.0 -5.0 mm/year.
(5) It is assumed that the damage is proportional to distance of ice movement and contact pressure.
(6) Lakes near by bridge increses the damage.

The aboves indicate that the damages are caused by abrasion between the concrete surface of pier and river ice movement.

Damage on concrete surface by abrasion induces the deterioration of concrete surface because the abrasion increases surface area exposed to water and air. Moreover, change of the pier shape results in increase of horizontal and vertical forces from ice sheet. Therefore, protecting concrete pier from abrasion becomes very important in designing bridge pier in Hokkaido.

This paper reports the methoc ›n concrete pier, then proposes the preve

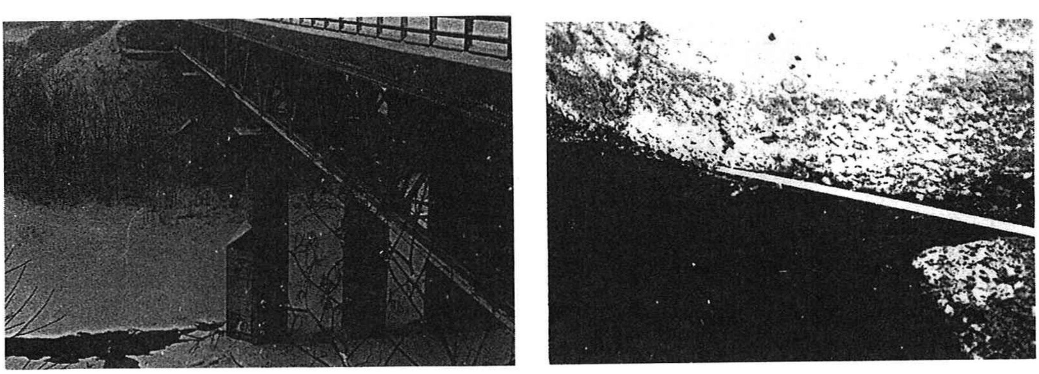


Figure 1. Damaged bridge piers by ice movement

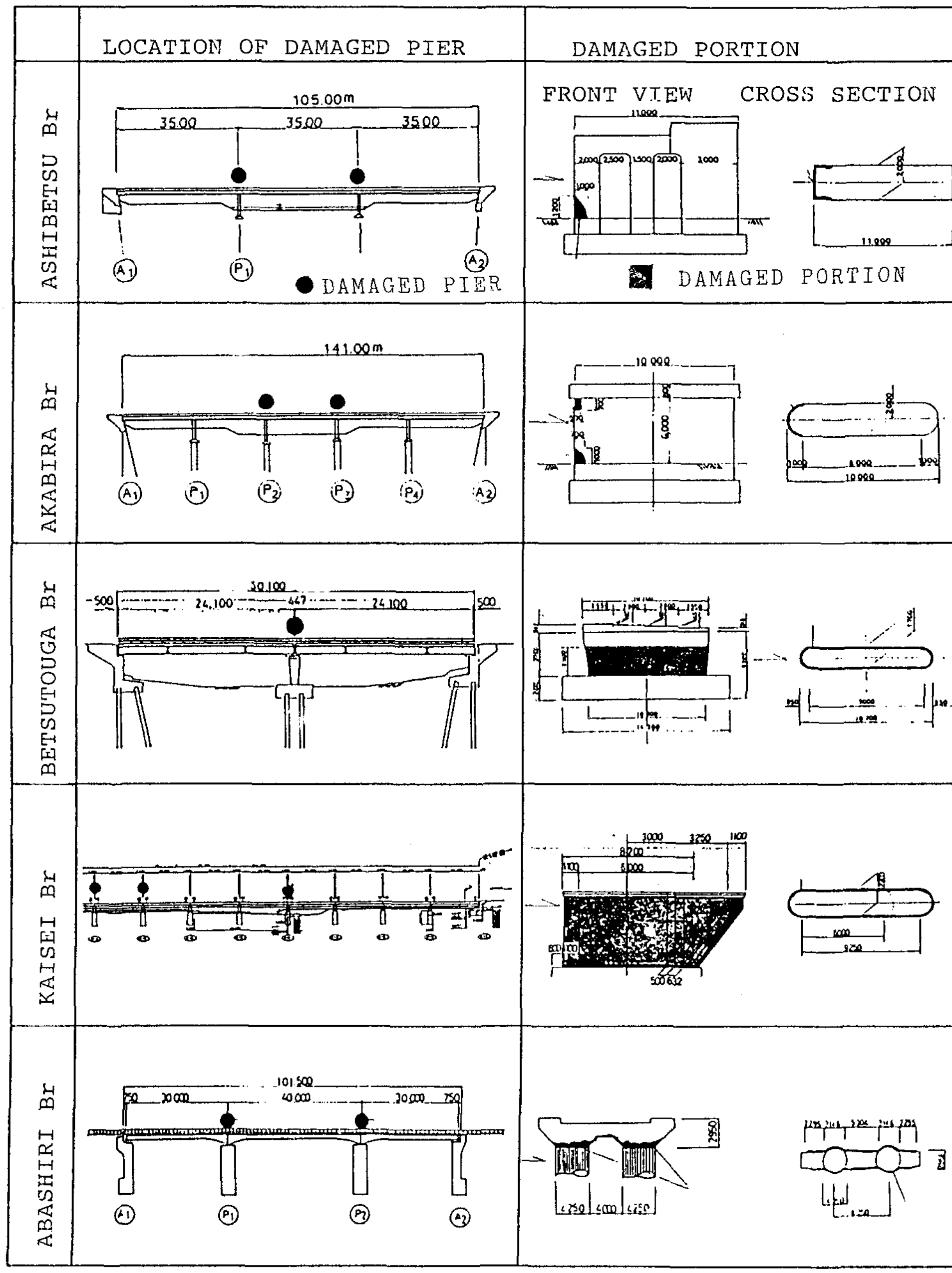


Figure 2. Bridge pier damaged by ice movement

2. EXPERIMENTAL APPARATUS AND PROCEDURE

In order to make friction between ice block and concrete piece the equipment shown in Figure 3 was used. In this figure sliding plate slides horizontally and reciprocally.The concrete piece is pressed on ice block on sliding plate. Pressure between ice and concrete suraface is variable in the range of 0 - 500kgf/cm². Velocities of sliding plate are changeable in 1.0 cm/s, 5.0 cm/s and 20 cm/s. For controling temperature on the surface of ice compressed air whose tempereture is equal to that of cold room is blown on the ice surface. At the same time the air blows the slugs of ice and concrete off.

A light weight aggregate concrete which has 570Kg/cm² uniaxial strength is tested. Width of the test piece is 10 cm. For comparing the experimental result of concrete pieces with other material the abrasion rate of low density polyethylene is examined in this experiment.

It is interesting to compare the experimental result of pure water ice with that of sand suspending ice because natural ice in river and lake always contains sand particles.

Content of sand particles in the ice block is expressed as (weight of sand / weight of ice) * 100 %.

The emphasises of this experiment are clearig relationships between the abration rate and ice temperature, contact pressure and content of suspending sand.

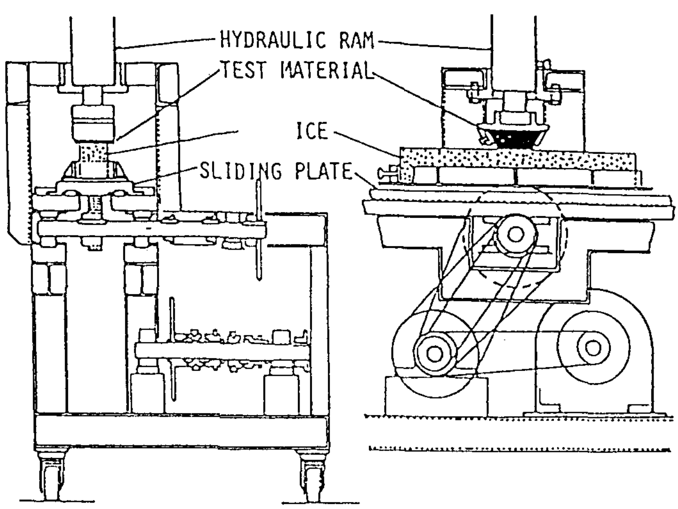


Figure 3. Abrasion testing machine

3. EXPERIMENTAL RESULT

Figure 4 shows an example of the abrasion test on concrete surface. In this experiment velocity of ice sliding is 5.0cm/sec. The contact pressure is 10 Kgf/cm². Ice tempereture is -20°C. Sliding distance is 5 Km. Abrasion amount is measured at five dotted lines; S1,S2,S3,S4 and S5 by a micrometer as shown in this figure. In this figure (A) shows surface roughness before the abrasion test, and (B) shows after the abrasion test. The maximum abrasion amount in each dotted line reaches up to 0.2 - 0.5 mm.

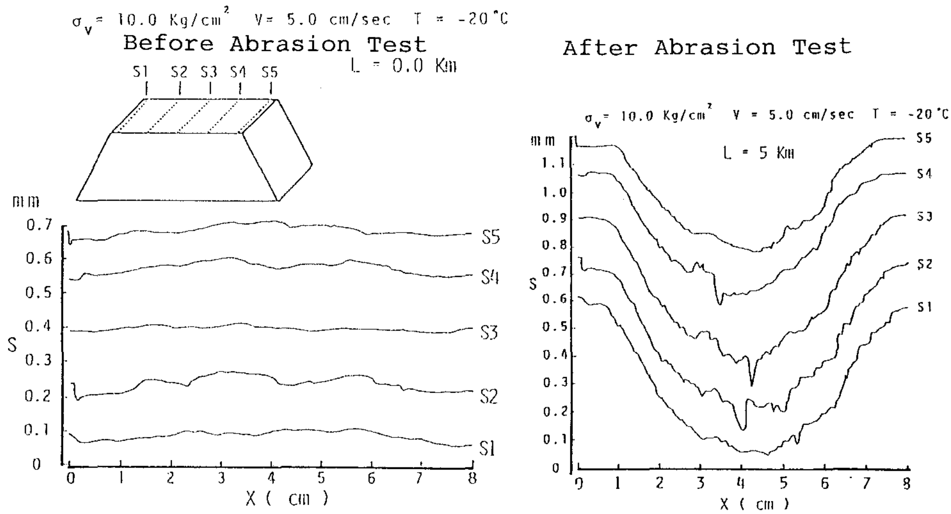


Figure 4. Surface roughness of a concrete piece before and after abrasion test

Figure 5 shows the relation between abrasion rate, contact pressure and ice temperature. The abrasion rate at lower temperature than -10° C is slightly larger than that of the higher temperature, while values at higher temperature than -10° C is almost constant. This figure also shows that the contact pressure is almost proportional to the abrasion rate.

Figure 6 shows the comparison of the abrasion rate between concrete and low density polyethylene. It is noted that the abrasion rate of low density polyethylene is 1/15 of that of concrete.

The above experimental results conclude that the abrasion rate depends on the contact pressure, ice temperature and material of pier.

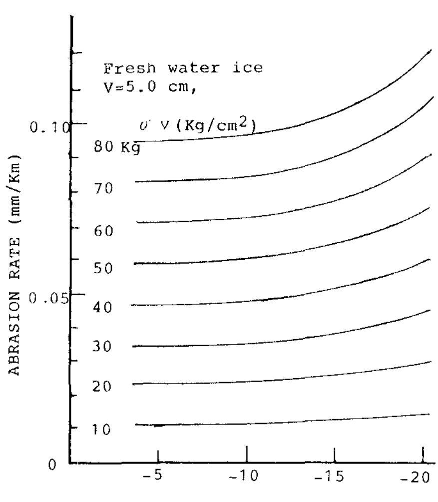


Figure 5. Relation between abrasion rate, contact pressure and temperature

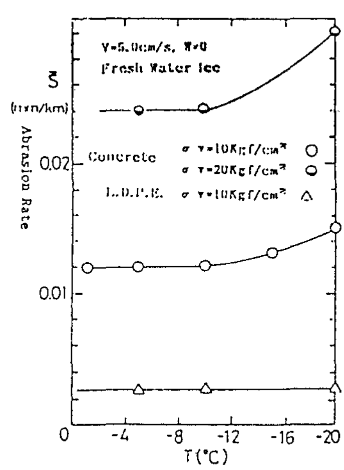


Figure 6. Abrasion rates of concrete and low density polyethylene

It has been reported that the natural ice always suspends sand particles. It is expected that sand particles cause larger frictional force to the surface of concrete structure because the salt particles suspended in sea ice increase the abrasion rate (Saeki et al, 1986). Figure 7 shows the effect of diameter of sand particles on the abrasion rate. In this experiment content of sand particles is 0.4%, ice temperature is -10°C and sliding velocity is 5cm/sec. The mode diameter of the sand particles used in this experiment were 0.03, 0.14 and 0.7 mm. It is very clear that the sand particles suspended in ice increases the abrasion rate comparing with that value of pure ice, and the larger sand diameter provides the larger abrasion rate.

Figure 8 shows the effect of the content of sand particles on the abrasion rate. This figure shows that large content of sand particles in the ice results in the large abration rate.

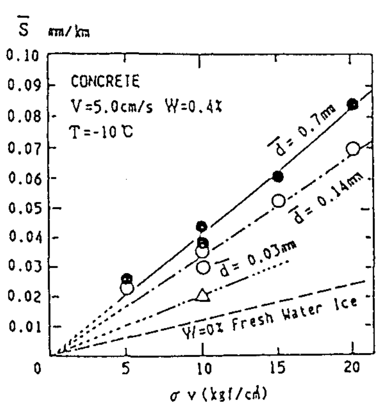


Figure 7. Relation between abration rate and sand diameter

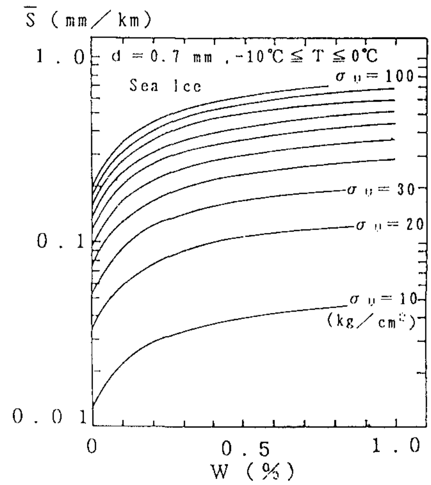


Figure 8. Effect of content of sand on abrasion rate

4. DISCUSSION AND CONCLUSION

The estimating method of the abrasion amount is depicted in Figure 9 by using factors which have influences on the abrasion rate. The experimental results show that the most important factors for reducing the abrasion rate by ice movement in river are the contact pressure, temperature, materials of the pier and content of sand particles suspended in river ice. In these factors the contact pressure can be controled by designing the shape of pier and the materials of pier can be selected when it is designed.

The most effective way for reducing the contact pressure is to adopt the shape of cross section which provides the smallest force to the pier. Figure 10 shows indentation of concrete pier which has cross section of wedge shape to ice sheet. Saeki(1989) reported that wedge-shape cross section reduced the ice force to 50-70% of square-shape cross section.

Figure 11 shows the effect of inclination of nose. In this figure, Fh/F expresses the ratio between ice force of vertical pier and that of inclined pier. This figure shows that nose inclination of 70° reduses ice force to 50% of vertical pier nose. Therefore, wedge-shape and inclined pier nose provides the smallest ice force. Moreover, the conbination of these shapes and covering the nose with the materials such as low density polyethylene which are durable to the abrasion as shown in figure 6 provides the largest durability to concrete bridge pier.

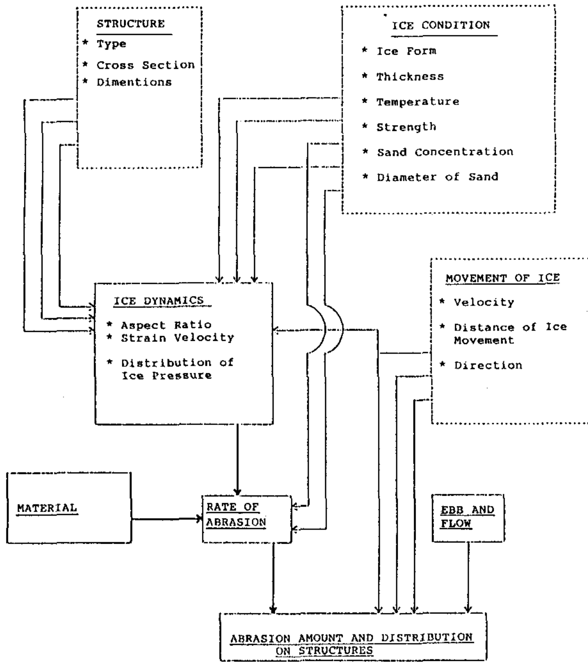
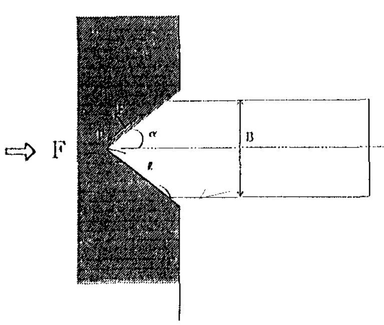


Figure 9. Flowchart for estimating abrasion amount by ice movement



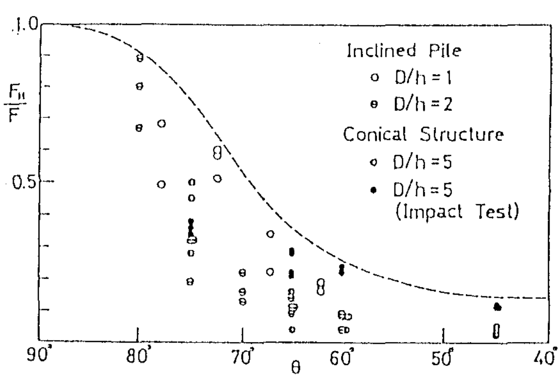


Figure 10. Indentation of wedge-shape pier to ice sheet

Figure 11. Effect of pier inclination on reducing ice force

REFERENCES

Itoh et al., "An Experimental Study on Abrasion of Concrete Due to Sea Ice", Proc. of Offshore Technology Conference, Vol. 2, p 61-68, 1986

Saeki et al., "The Coefficient of Friction between Sea Ice and Various Materials Used in Offshore Structure", Jour. of Energy Resources Tech., ASME, Vol. 108, P. 65-71, 1986