

APPLICATION OF RUBBER BONDED CONCRETE BLOCK TO ANTI-SLIP PAVEMENT UNDER SNOW CONDITION

T. Horiguchi, A. Kasahara
Hokkaido Institute of Technology, Sapporo, Japan

A. Niida
Civil Eng. Services Co. Ltd., Sapporo, Japan

H. Arai
Hokkaido Government, Sapporo, Japan

Summary

In this paper, a rubber-bonded concrete block, which consists of a rubber surface, steel interface and a concrete block, is proposed as a snow-and-ice removal system in winter. It is named the rubber-bonded concrete block as ASSEC (Anti-Slip Small Element Concrete), and three major evaluations and in situ applications were conducted. Evaluations were made of durability tests, tests for pavement friction and wear resistance carried out on the concrete block pavement.

As a durability study, three types of fatigue tests were conducted to evaluate the durability of the bond between the steel and concrete interface. The fatigue tests were conducted under room temperature as well as freezing and thawing condition. Wear resistance was measured and compared with other popular pavement materials such as cement concrete and bituminous concrete. Skid resistances of the pavements were measured for pavement friction using a Portable Dynamic Friction Tester, in wet conditions.

Test results of durability, pavement friction and wear resistance showed the feasibility of application to anti-slip pavement. Finally, ASSEC paving of more than 1,100 m² was constructed at 21 locations in Hokkaido for in situ evaluations of the serviceability, safety and durability.

INTRODUCTION

Sapporo, with a population of approximately 1.8 million, is the largest city in Hokkaido, the northernmost island of Japan. Sapporo was host to the Winter Olympic games in 1972. No other big city in the world has such a large snowfall in one winter season as Sapporo (approximately 5 meters). Recently, snow-and-ice removal techniques have become an urgent subject of research to overcome the anti-slip problems. Problems related to ice and snow have had very adverse economic effects in Sapporo and other districts in Hokkaido since 1992, the year when the use of studded tire was prohibited to solve the problem of environmental pollution. Removal of ice (and compacted snow) from road surfaces has been accomplished in part by using ice-and-snow melting techniques (eg. road heating by electric energy) or deicing chemicals. However neither the combination of these methods nor their independent use has proven completely satisfactory. Although environmental pollution has been greatly reduced, an increase in automobile accidents and pedestrians injuries has created a new serious problems. A better understanding of the conditions under which anti-icing is effective and how to conduct anti-icing efficiently is needed to resolve these problems.

This paper proposes an ASSEC(Anti-Slip Small Element Concrete) paving technique for effective and efficient removal of snow and ice. ASSEC is a rubber-bonded concrete block, which consists of a rubber surface, steel interface and a concrete block. The successful removal of ice and compacted snow was demonstrated by experiments using a flexible elastic surface made of the blended rubber which has a characteristic of low adhesion to ice and snow. Durability and wear tests were conducted to evaluate the application feasibility of the anti-icing ASSEC paving. A method for improving the coefficient of friction on a bare surface was also discussed because a rapid decrease in friction is necessary, especially in rainy days in summer.

ANTI-SLIP SMALL ELEMENT CONCRETE

The main purpose of ASSEC paving technology is to improve traffic safety in winter, by removing ice and compacted snow on road surfaces. ASSEC paving technology can increase the friction coefficient between non-studded snow tires and the road surface, or between shoes sole of pedestrians and the sidewalk surface.

Physical properties of the rubber

The rubber used in ASSEC is a blend of natural rubber(NR) and synthetic rubber(SBR). Table1 shows the physical and mechanical properties of the rubber.

Bonding property

The idea of making a rubber bonded concrete slab is not new. Coating or tipping rubbers has been used for a long time to pave concrete surface. However, an adhesion between a concrete surface and rubber is relatively low value, there is a problem of durability of bonding between the rubber and concrete interface. To overcome this difficulty, a steel plate interface was used between the concrete surface and rubber. The excellent adhesion between the rubber and steel plate is necessary for maintaining an effective bond strength between the steel plate and concrete. As steel anchor systems in concrete structures have often shown excellent bonding

behavior, a good bonding performance between a steel plate and concrete surface can be expected. Fig.1 shows a schematical representation of ASSEC, which is composed of three elements, namely a rubber plate, a steel plate with an anchor stay and a concrete block. As shown in the figure, an interfacial treatment between the steel plate and concrete block was used on some specimens. Interfacial treatment was conducted by placing workable mortars on top of the concrete block, which was made of zero slump concrete. This helps to improve the adhesion between the steel plate and concrete block which is relatively weak.

DURABILITY

Delamination index

Three types of durability tests were conducted to evaluate the bond (or delamination) behavior between the steel and concrete interface with or without interfacial treatment. The durability of the bond between the steel and concrete interface was evaluated as the delamination index, which is defined as follows. Five points, including each of the 4 corners and the center of the ASSEC specimen were sounded by a steel test hammer. The degree of delamination was judged by the hammer sounds at each point, and was scored as 2 points for delamination, 1 for suspectable delamination and 0 for non-delamination. The total score of the 5 points is added and defined as the delamination index.

Cyclic loading test

For the cyclic loading test, maximum and minimum loads of 2,000 kgf (38.2 kgf/cm²) and 500 kgf (9.6 kgf/cm²), respectively, were applied to one ASSEC specimen with 8 Hz sinusoidal loading.

Fig.2 shows the test results of the cyclic loading tests. After 30,000 times of cyclic loading, the specimens with the interfacial treatment showed the excellent durability, while the untreated specimens showed some delamination behavior.

Impact loading test

The impact fatigue test apparatus has a 4,536 g (10 lb) sliding weight with a free fall of 457.2 mm (18 in.). These tests simulated delamination due to repeated (impact) actions from traffic load on the block pavement. The applied impact load F can be calculated as

$$F = \sqrt{mgh} \quad \dots (1)$$

where m is the sliding weight and h is the free fall. Substituting the value of $m=4.536$ kgf and $h=457.2$ mm, we get $F = 450$ kgf.

Fig.3 shows the results of impact loading tests. After 10,000 times of cyclic loading, the specimens with the interfacial treatment showed the high durability, while untreated specimens showed a high delamination index. Although the magnitude of the impact load was about 4 times smaller than that of the cyclic loading, the impact test showed more significant delaminations than that of the cyclic loading test.

Impact loading test under freezing and thawing

An impact loading test was conducted under freezing and thawing cycles on a water-saturated specimen. The target freezing temperature was -25°C . The impact loading was applied after each 10 cycles of freezing and thawing. The delamination index was scored after 10 times of impact loading.

Fig.4 shows the test results of impact loading tests under freezing and thawing conditions. After 50 cycles of freezing and thawing, the specimens with the interfacial treatment showed excellent durability, while adhesion in untreated specimens was lost its adhesion.

PAVEMENT FRICTION

Pavement friction is one of the major factors affecting the quality and performance of pavements. Pavement friction should be maintained at a certain value even in rainy days in summer. As the skid resistance of a rubber surface is relatively low in wet condition, ASSEC paving was added to ordinary concrete blocks to improve the pavement friction. The pavement friction was measured while varying the mixture ratio of ASSEC from 50 % to 100 %.

The skid resistance of the pavements was measured using a DF (Dynamic Friction) Tester [1] in wet conditions. The DF Tester is a compact and portable device which can measure skid resistance and speed dependency of pavement surfaces. The apparatus used in this study is a disc-rotating type tester, which was used to measure the friction force between the surface and three rubber pads attached to the disc. The disc rotates horizontally at a linear speed from about 80 km/h to 20 km/h under a constant load. The DF Tester can measure the skid resistance at any speed in this range, at one site with a single measurement. The results also show speed-dependency of skid resistance which will be as close as possible to the results obtained by other testing modes.

Fig.5 shows the change in the pavement friction measured by the DF Tester with increases in the measuring speed from 20 km/h to 60 km/h. The coefficient of friction increased as the mixture ratio of ASSEC decreased, and decreased as the measuring speed increased. The coefficient of friction of the rubber surface was 0.2 and 0.38 at measuring speeds of 60 km/h and 20 km/h, respectively. However the addition of 25 % ordinary concrete block improved the coefficient of friction to 0.35 and 0.57 at measuring speeds of 60 km/h and 20 km/h, respectively. These results indicate that for the use of ASSEC paving on roads, a mixture of ASSEC and minimum of 25 % ordinary concrete blocks, with good uniformity, is preferable.

WEAR RESISTANCE

Wear resistance is another major factors affecting the quality and performance of pavements [2],[3]. Wear tests were conducted using the ASTM C 944 method [4]. This test method has been successfully used in the quality control of concrete in highways and bridges which are subjected to traffic loads. The wear resistances of comparative concrete (plain concrete and fiber reinforced concrete) and bituminous materials were also measured under the same conditions.

Fig.6 shows the wear rate of different paving materials, bituminous concrete, plain portland cement concrete, fiber reinforced cement concrete, zero-slump cement concrete and rubber of

ASSEC paving. It is clear that the rubber is the most wear resistant material, with wear resistance 10 times higher than bituminous concrete and 3 times higher than cement concrete.

APPLICATION OF ASSEC PAVING

After confirmation of basic durability and effectiveness of anti-icing properties, ASSEC paving of more than 1,100 m² was constructed at 21 locations on streets in Hokkaido. Most of the locations were intersections and pedestrian crossings. As an in situ evaluation, anti-icing effectiveness, the serviceability, traffic safety and durability were evaluated.

Fig.7 shows an application of ASSEC paving on a pedestrian crossing in winter. Ice and snow was effectively removed allowing pedestrians to cross without any risk of slipping. Fig.8 shows an application of ASSEC paving on a street. Vehicles could be driven on the bare surface with a relatively high coefficient of friction in wet conditions.

CONCLUSIONS

The results of durability, pavement friction and wear resistance tests, showed the feasibility applying ASSEC paving to anti-slip pavement. ASSEC paving of more than 1,100 m² was constructed at 21 locations in Hokkaido for in situ evaluations of serviceability, safety and durability. In situ applications showed excellent anti-icing action and good durability and safety.

REFERENCES

- [1] K. Saito, A. Kasahara and N. Konagai; The Development of a Test Equipment for Measuring Pavement Skid Resistance Based on the Method of Differential Wheel Rotation Speed, Proceeding of Second International Symposium of Road Surface Characteristics, pp.151-163, 1992.
- [2] T. Horiguchi, A. Kasahara and S. Ikeda; Wear Tests on Concrete Block Paving Materials, Proceeding of Second International Workshop of Concrete Block Paving, Oslo, Norway, pp.89-96, 1994.
- [3] B. Shackel and X. Shi; The Abrasion Testing of Concrete Pavers, Proceeding of Fourth International Concrete Block Paving Conference PAVE 92, pp.229-238, 1992.
- [4] American Society for Testing and Materials: Standard Test Method for Abrasion Resistance of concrete or Mortar Surfaces by the Rotating-Cutter Method, 1991 Annual Book of ASTM Standards, Section 4 Construction, Vol. 04.02, pp. 483-487.

Table 1 - Physical and mechanical properties of the rubber

color	hardness	elongation	Poisson's ratio	specific gravity	tensile strength	shear strength	feasible temperature
black or white	65±5	550%	0.46-0.49	1.2	230 kgf/cm ²	30 kgf/cm ²	-55°C (min.) +130°C (max.)

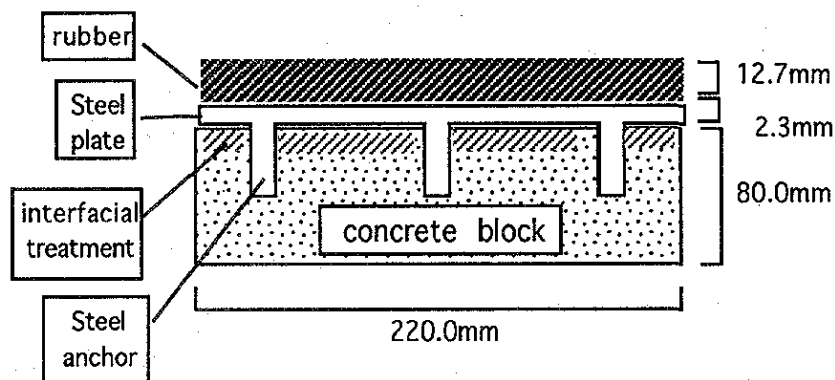


Fig. 1 - Schematical representation of ASSEC (Anti-Slip Small Element Concrete)

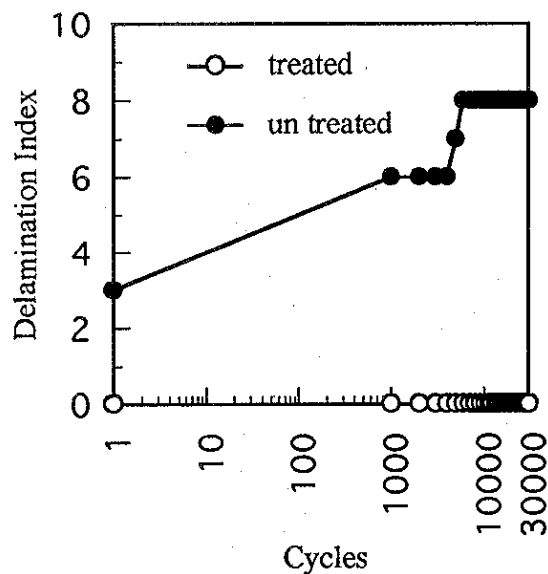


Fig. 2 - Effect of interfacial treatment on delamination (cyclic loading test)

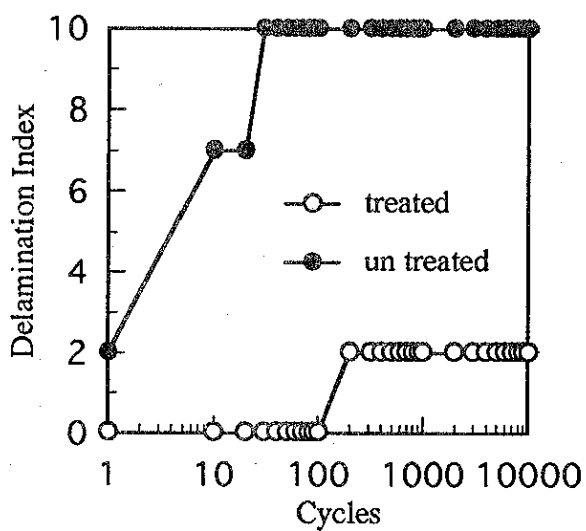


Fig. 3 - Effect of interfacial treatment on delamination (impact loading test)

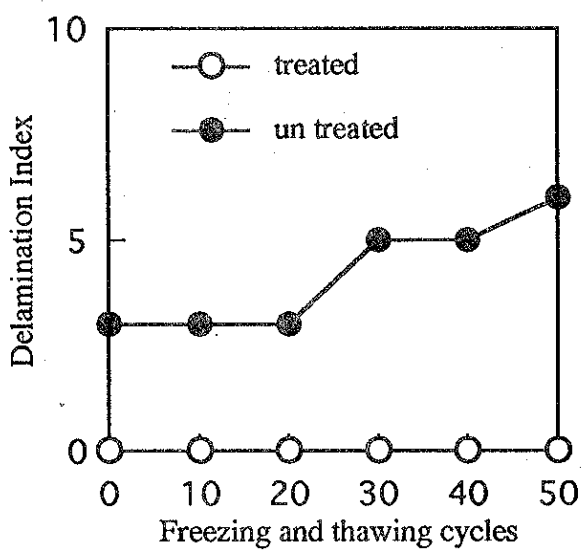


Fig. 4 - Effect of interfacial treatment on delamination (impact loading under freezing and thawing)

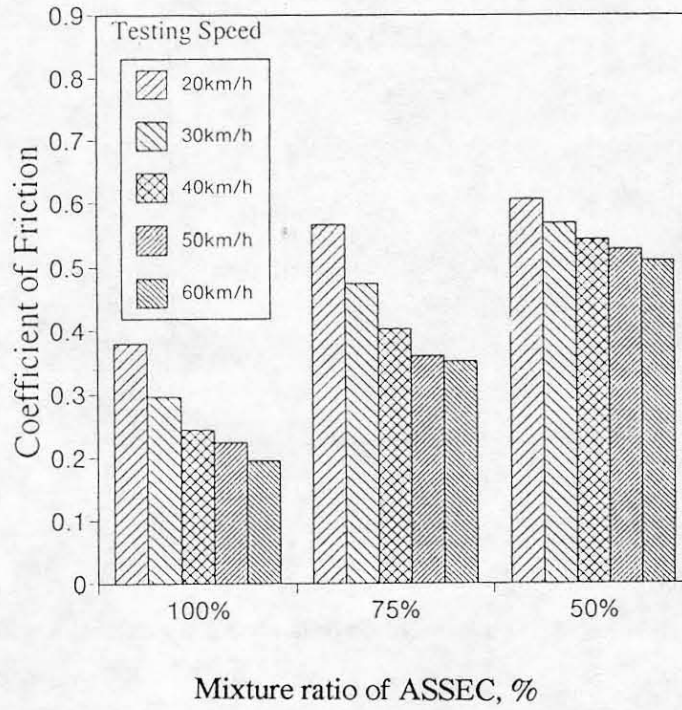


Fig. 5 - Changes in the coefficient of friction for variations in the mixture ratio of ASSEC

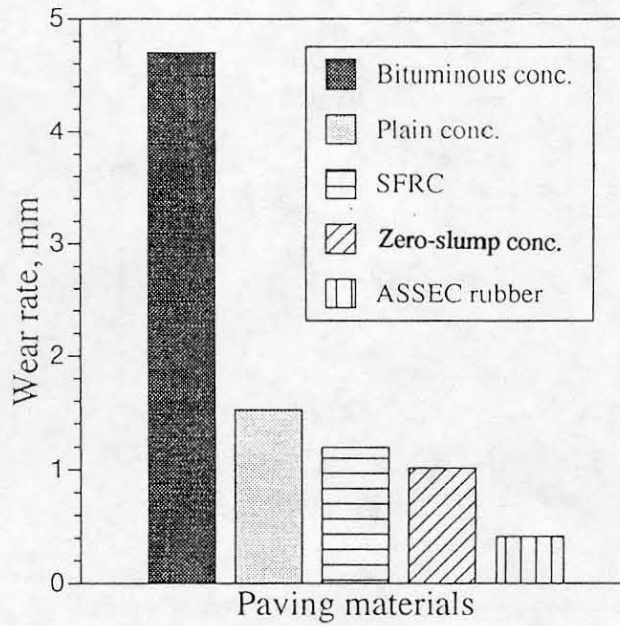


Fig. 6 - Wear rates of paving materials



Fig. 7 - ASSEC application to pedestrian crossing in winter



Fig. 8 - ASSEC application to street paving