A STUDY ON APPLICATION OF TEXTILE SURFACE MATERIAL FOR SHOCK ABSORBING PAVEMENT

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Abstract

In long tunnels in snowy regions, motor vehicles have to remove and reinstall tire chains at the areas before and after the tunnel to prevent them from being broken in time of snowfall, and within the tunnel they run with tire chains removed. In the heavy traffic season, traffic jams result from the removal and reinstallation of tire chains. In order to clear up such traffic jams, it has been desired to develop a pavement that allows vehicles to run with tire chains installed (shock-absorbing pavement).

In this study, we investigated a textile surface material for possible application for shock-absorbing pavement in collaboration with the Japan Highway Public Corporation. The features of this material are as follows:

1) High elasticity allows to absorb impact loads of running vehicles.
2) Great tensile strength and high tear resistance ensure good resistance to abrasion by chains and high durability.
3) Color brightening is possible, and tunnel brightness comparable to that of concrete pavement can be expected.
4) Construction is simplified (prefabrication).

In this study, necessary functions for use in long tunnels were at first investigated in laboratory tests and, based on the investigation results, a test pavement was constructed in an actual tunnel to evaluate its serviceability. The results of the study are given below.

Results of laboratory tests:

o The maximum depth of wear measured by enhanced wear test is nearly one-half of that of concrete.
o Chain damages are far less than those on concrete pavement.
o The rebound ratio measured using golf balls and the measured value of impact acceleration are considerably lower than those of concrete, proving excellent shock absorbing ability.

Test pavement (actual road in tunnel):

The test pavement was constructed in the Ishiuchi tunnel section of the Kan-Etsu Expressway. The results are as follows.

o No such damages as pot-holes and stripping were observed, proving excellent adhesion.
o No rutting was observed even two years after construction, proving excellent abrasion resistance.
o The skid resistance tended to decrease slowly.

From the above results, it can be concluded that this material is sufficiently applicable for

shock-absorbing pavement though the problem of skid resistance remains to be solved.

1. Introduction

In long tunnels in snowy regions, motor vehicles have to remove and reinstall tire chains at chain stations to prevent them from being broken under snow loads. This gives rise to traffic jams in the heavy traffic season. In order to clear up such traffic jams, it has been desired to develop a pavement that allows vehicles to run with tire chains (non-metallic) installed. In 1996-1998, therefore, the Japan Highway Public Corporation (called "JH"), Watanabegumi Co., Ltd. and TOA Road Industry Co., Ltd. carried out a joint study with a view to making use of a textile material to develop a pavement capable of absorbing shocks to non-metallic chains (rubber net chains) (called "shock-absorbing pavement").

2. Development Objectives

In this joint study, the following items and development objectives were defined to investigate the shock absorbing pavement for use in tunnels:

1) Investigation on abrasion resistance

o Abrasion resistance equal to that of the concrete surface:

As the existing surface was a concrete surface, an abrasion resistance not less than that of the concrete surface was specified for application of the shock-absorbing pavement in the tunnel.

2) Investigation on the effect of chain break prevention

o No damage to non-metallic chains even after 500 km of continuous running at 70 km/h:

From a survey of the running condition in the Yuzawa area of the Kan-Etsu Expressway during the winter season in which use of tire chains is mandatory, a running speed of about 70 km/h was judged reasonable as a development objective. In addition, the results of testing passenger-car tires with generally used non-metallic chains (Mighty Net EL-6) on the concrete surface by a simulator at the JH Testing Laboratory showed no damage after not less than 500 km of continuous running.

3) Investigation on skid resistance

o More than BPN60

In laboratory tests for this development, the standard value of BPN specified in the JH Construction Control Procedure (Pavement) was adopted. Verification of skid resistance by a test vehicle was decided to be done after construction of the test pavement.

4) Investigation on burning resistance

o Equivalent to "incombustibles" in the Basic Evaluation Method "A-A "Mode"

At present, there are no criteria applicable to the burning resistance of the pavement surfaces. However, it was decided to make sure the paving material itself does not get or spread fire because the pavement is intended for use in long tunnels. It was also decided to evaluate the burning resistance of the material according to the Basic Evaluation Method "A-A "Mode" which specifies the criteria for evaluating the combustibility of materials for the railway wagon.

3. Textile Surface Material

The structure and features of the textile surface material are given below.

3.1 Structure of the textile surface material

The textile surface material is prepared by using as its base fabric a core of synthetic fiber such as polyester covered with an unwoven fabric of synthetic fiber such as polyester and impregnating the base fabric with a rubber-mixed synthetic resin. The thickness of the material is 6-8 mm. The cross section of the material is shown in Figure 3-1.

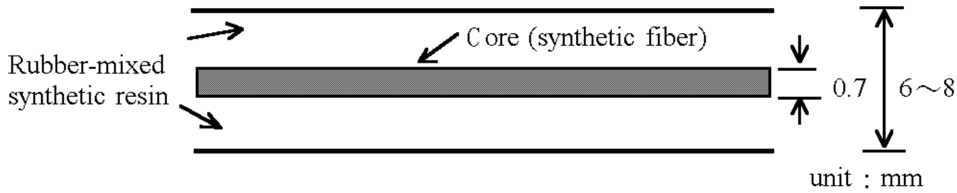


Figure 3-1 Cross section of textile surface course material

3.2 Features of the textile surface material

The features of the textile surface material are as follows:

1) Uniform product quality ensured by shop fabrication
2) Prefabrication of pavement structure by shop cutting of product
3) Excellent in tensile strength and tear resistance owing to use of synthetic fiber as base fabric
4) Lower in unit weight than other paving materials
5) Much more elastic than other paving materials

Table 3-1 shows the properties of the textile surface material.

Table 3-1 Properties of Textile Surface Material

Direction of rolling up	Longitudinal	Lateral	Test method
Tensile strength (kN/5 cm)	1.4	3.7	JIS L 1079
Elongation (%)	110.0	100.0	JIS L 1079
Tear resistance (N)	127.4	215.6	JIS L 1079
Water repellency	80.0		JIS L 1079
Unit weight (g/cm$_3$)	0.7		
Water absorption (%)	31.0		JIS L 1079
Elastic modulus* (kPa)	5300 (330000***)		
Rebound ratio** (%)	32.4 (78.9***)		

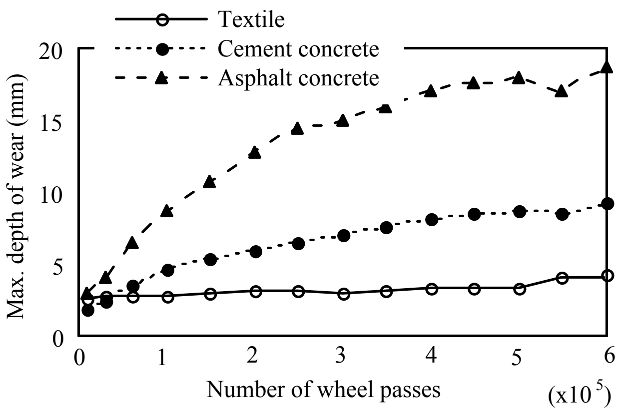
* At 2 mm penetration of stud ** By golf ball
*** Asphalt pavement

4. Results of Laboratory Tests

In the laboratory tests, abrasion resistance, skid resistance and the effect of chain break prevention were first investigated using an enhanced wear test machine and finally evaluated by means of a test simulator. The test results are given below.

4.1 Abrasion resistance

Figure 4-1 shows the relation between the depth of wear and the number of wheel passes measured by the test simulator. As seen from the figure, with asphalt concrete and cement concrete, the depth of wear increases with increasing number of wheel passes, while with the textile surface material the depth of wear virtually does not vary. Therefore, it can be presumed that practical application of the material for roads will involve no problem in terms of wear.



Test conditions
Tires: Passenger-car tires, single
Wheel load: 4 kN
Chains: Mighty net EL-6
Running speed: 70 km/h
Test temperature: 0℃

Figure 4-1 Results of simulator test

4.2 Skid resistance

Figure 4-2 shows the relation between skid resistance (BPN) and the number of wheel passes in the simulator test. As seen from the figure, the skid resistance of the textile surface material is about 55 (BPN) and varies to some degree until after 200,000 passes, but stabilizes at about 60 (BPN) after 200,000 passes. From these results, it can be concluded that the textile surface material when put to practical use for roads will maintain a value very close to the target of BPN60.

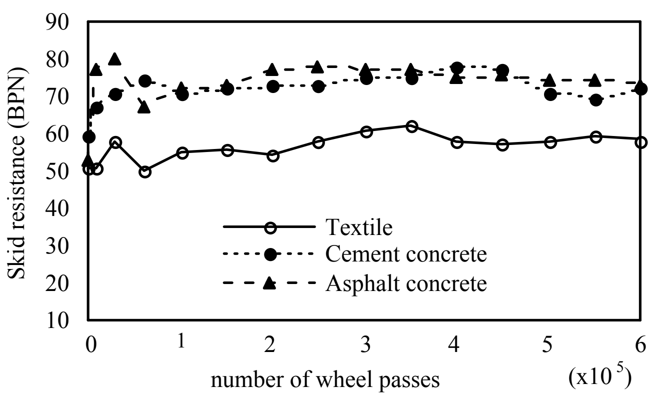


Figure 4-2 Results of skid resistance (simulating test)

4.3 Effect of chain break prevention

The effect of chain break prevention was evaluated from the weight loss and damaged state of the chains subjected to the enhanced wear test. To investigate the elasticity of the pavement that is assumed to affect the effect of chain break prevention, elasticity tests were conducted on a simulation test specimen with golf balls (shock absorption) and with steel balls (rebound by elasticity) (Supplement to the Pavement Test Procedures, Japan Road Association), and impact acceleration measurements were made by dropping a weight (4 kg from a height of 50 cm) (performed to evaluate the condition of riding grounds at the Japan Racing Association). The results are summarized as follows:

o As seen from Figure 4-3 illustrating the change in weight of chains, the chain weight shows a loss of about 2% in 20 hours after the start of test in case of the textile surface material. While in case of cement concrete and asphalt concrete the chain weight shows a loss of more than 10% in 20 hours after the start of test. The evaluation of the weight change reveals that the degree of damage to the chains on the textile surface material is approximately 1/5 of that on concrete.

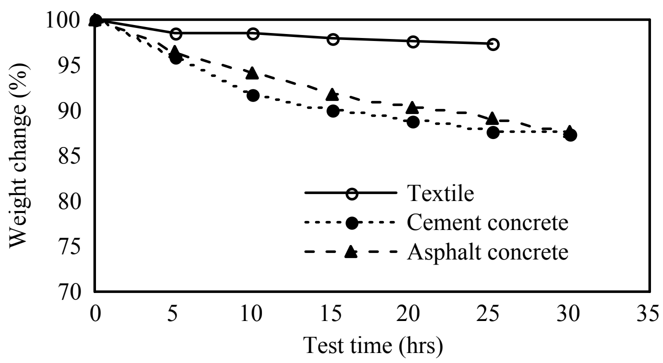


Figure 4-3 Change in Chain Weight

o The investigation of chain damages reveals that with the textile surface material the fibers that form the core of the rubber net begin to appear 15 hours after the start of test and the number of visible fibers increases even after 20 hours, but the fibers themselves remain unbroken. On the other hand, in case of concrete the fibers begin to appear after five hours and all of the outer fibers are broken after 20 hours. Referring to stud damages, there is no stud coming off even after 25 hours in case of the textile surface material. While with concrete some studs (12 out of 31 outer studs) begin to come off after five hours and all of the outer studs come off after 15 hours.

o As shown in Figure 4-4, the rebound ratio of the textile surface material in the drop test with golf balls is about 20% lower than those of asphalt concrete and cement concrete, which proves that this material is soft and elastic. On the other hand, the rebound ratio with steel balls is 12-14% for the textile surface material as well as for asphalt concrete and cement concrete, so the rebound ratio does not vary with the kind of material. In addition, with the textile surface material, the impact acceleration is lower by 140G and 190G than those with asphalt concrete and cement concrete, respectively, as shown in Figure 4-5, therefore, the textile surface material has a high shock absorbing ability.

According to the above results, the textile surface material is very elastic and reduces the degree of chain damage considerably as compared with concrete. Therefore, it can be concluded that the material will be sufficiently functionable as a shock-absorbing pavement material.

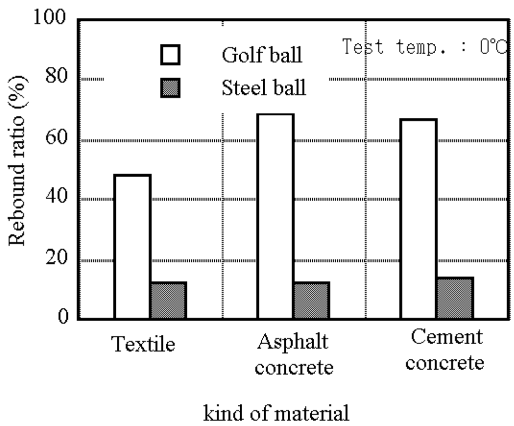


Figure 4-4 Results of Elasticity Test

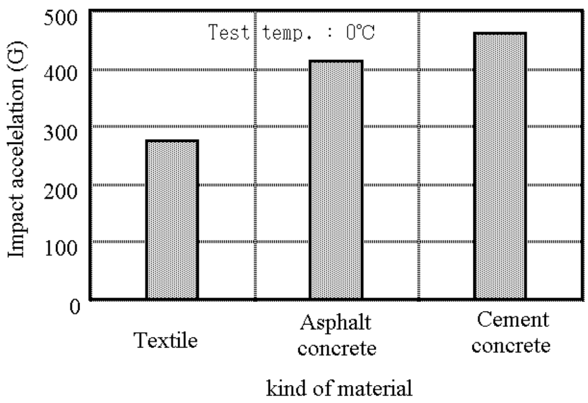


Figure 4-5 Results of Impact Accelelation Test

4.4 Burning resistance verification test

At present, there is no standard on the burning resistance of materials for pavements in tunnels. In long tunnels, however, the flames from vehicles catching fire due to an accident may spread to paving materials, resulting in a great disaster.

Therefore, the burning resistance of the textile surface material used here was verified by the JR Burning Test Procedure for railway wagon (A-A Mode). The test results are given in Table 4-1.

Table 4-1 Results of Burning Test

Combustibility evaluation criteria for textile surface material						Product	
Type		Inconbus-tible	Very resistant to burning		Resistant to burning	Conventional	Modified
During alcohol burning	Fire	Non	Non	Seen	Seen	Seen	Non
	Flame	Non	Non	Seen	Seen	Seen	Non
	Smoke	Very little	A little	A little	Normal	Much	A little
	Fire force	-	-	Weak	Doesn’t cross over top end	Crosses over top end	Doesn’t cross over top end
After alcohol burning	Remaining flame	-	-	Non	Non	Seen	Non
	Residual dust	-	-	Non	Non	Seen	Non
	Carboniza--tion	>100 mm	Doesn’t cross over top end	>80 mm	Doesn’t cross over top end	145 mm	110 mm
	Deforma-tion	>100 mm	>150 mm	>150 mm	Deformation extending to edge and local through-holes	50 mm	0 mm
Evaluation of burning resistance						Unacceptable	Acceptable

As shown in Table 4-1, the burning resistance of the original textile surface material of conventional type was judged unacceptable. Therefore, the material was modified by changing the kind of rubber impregnated into the base fabric and impregnating the base fabric with a combustion inhibitor. As a result, the material could satisfy the criteria. In this connection, it is to be noted that this modified product was a prototype in the laboratory test stage.

5. Test Pavement

A test pavement was constructed in order to obtain necessary data for grasping the skid resistance and adhesion on an actual road and for investigating construction methods for the developed shock-absorbing pavement

5.1 Description of the test pavement

An outline of the test site is given in Table 5-1, and the structure of the test pavement is shown in Figure 5-1. In the cross section of the figure, stone matrix asphalt (maximum grain size: 5 mm) was used as an underlayer. As the maximum rut depth in the existing pavement surface was 18 mm, the surface was milled to a depth of 30 mm and shot blasted, after which the underlayer was laid in a thickness of 24 mm.

Table 5-1 Outline of Test Site

Date of construction		Sept. 29, 1997, to Oct. 3, 1997
Location		Ishiuchi Tunnel, Kan-Etsu Expressway
Dimensions	Width	3 m
	Length	100 m
	Area	300 m^2
Existing pavement		Concrete pavement

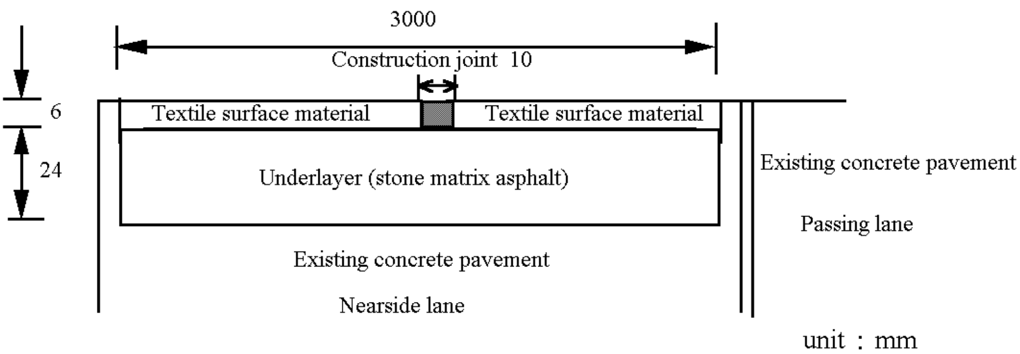


Figure 5-1 Cross Section of Test Pavement

5.2 Construction method

The adopted method of construction was that spreading adhesive beforehand and laying textile material on it. Therefore, the selection of the adhesive and the surface condition are important.

Various kinds of adhesives were investigated. As a result, rubberized asphalt (roofing material) was found to provide best adhesion. Concerning the surface condition, it is important that the surface be dry and free from contaminants. Figure 5-2 shows the flow of construction.

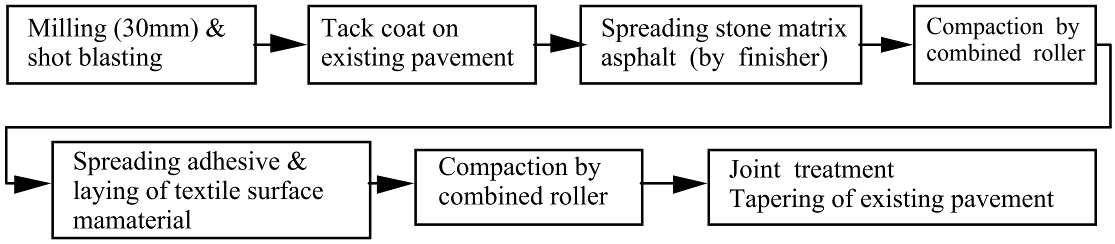


Figure 5-2 Flow of costruction

5.3 Performance of the test pavement

The results of the survey made immediately after construction are summarized in Table 5-2.

Table 5-2 Test Results Immediately After Construction

Test item	Measuring method	Test result
Skid resistance	Large-sized skid resistance test vehicle (μ)	0.507 (test speed: 75 km/h)
	Portable skid resistance tester (BPN)	60
	Dynamic Friction tester (μ)	0.52 (test speed: 80 km/h)
Surface texture	Mini texture meter σ (mm)	Outer wheel path: 0.30 Inner wheel path: 0.32
Surface roughness	3m profile meter σ (mm)	Outer wheel path: 1.04 Inner wheel path: 1.12
Adhesion	Tensile strength test (kPa)	400
Shock absorbing ability (Elasticity test)	Golf ball rebound (%)	33
	Steel ball rebound (%)	9

The summary of the results is shown below:

o To investigate the skid resistance of the test pavement, the skid resistance coefficient was measured by a large-sized skid resistance test vehicle and a Dynamic Friction tester. The values measured by both testing machines were not less than 0.5 μ , which proves a good skid resistance. The BPN was 60, a value nearly equal to that measured by laboratory test.

o The surface texture measured by a mini texture meter was about 0.3 mm. This value is a little lower than that of conventional asphalt pavement (about 0.4 mm).

o The surface roughness was 1.04 for the outer wheel path and 1.12 for the inner wheel path. These values are good despite the short construction length of 100 m (the standard value for maintenance and repairs is less than 1.3).

o The adhesion measured by tensile strength test was 400 kPa. Though there are no definite criteria to specify what degree of adhesion is required for the textile surface material, no instance of stripping of the material has been observed for the last six years according to the past results of its applications using the same adhesive. From this fact, it can be concluded that there will be no problem with such a degree of adhesion.

o Concerning the shock-absorbing ability, the value measured using golf balls was about 10% lower than that measured by laboratory test (increase in elasticity).

5.4 Serviceability

o The surface condition during about two years after opening to traffic was satisfactory with no rutting and stripping with the exception of the tearing caused by the blades of snow removers in the vicinity of the opening of the tunnel.

o The skid resistance decreased gradually after opening to traffic, and the skid resistance coefficient decreased to about 0.2 μ (measured by the large-sized skid resistance test vehicle) after about two years. Presumably, this was due to permanent set and some consolidation of the textile surface material.

The test pavement exhibited no surface damage according to the above results, but was removed after about two years service, taking into account possible skidding accidents.

6. Future Problems

1) Method of application

It takes time to melt the adhesive and the high temperature of the molten adhesive may cause burn during spreading by man power. Therefore, it will be necessary to investigate a method of cold application.

2) Ensuring stable skid resistance

The decrease in skid resistance under service conditions is relatively great. Therefore, it will be necessary to improve the product to such a level as to ensure stable skid resistance.

7. Conclusion

In this study, a new textile surface material was investigated for possible application for shock-absorbing pavement. From the results of the study, it can be concluded that the initial development objectives have been attained as a whole. However, it will be necessary to improve the material further more in terms of skid resistance.

In conclusion, we wish to acknowledge the considerable assistance of the members of the Pavement Research Section, Testing Laboratory, and the Yuzawa Operation Office, Kanazawa Operation Bureau, Japan Highway Public Corporation, who took part in this study.