STRUCTURE OF DRAINAGE PAVEMENT

IN CONSIDERING MAINTENANCE OF ROAD SURFACE IN WINTER

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1. Abstract

This study is focusing on an optimum structure of drainage pavement. Ishikawa prefectural office has been constructing drainage pavements in densely populated areas since 1996 and the total length was about 50 km in 2000. A drainage pavement has both good and bad points. The followings have been revealed as good points. They are mitigation of hydroplaning, relief of splash followed by improvement of driver's visibility, easing reflection of a headlight on a road surface during a rainy night, increase of visibility for a traffic sign on the road surface in a rainy day, decrease of traffic noise and so on. On the other hand, several bad points were pointed out, especially, in a snow season. One of them is that it is easier for snow to pile up and remain on the drainage pavement than normal pavement and harder to remove the compressed snow. The effectiveness of antifreeze and water spray from a water pipe under the road to melt snow seem to be reduced by the drainage pavement.[1)]

The present paper tries to propose an optimum structure of drainage pavement for solving the problems in a snow season. Firstly, effects of maximum grain size and void ratio of materials on permeability of a pavement and the performance in a snow season were investigated in a laboratory. Next, new materials of a drainage pavement were examined. Laboratory tests were conducted by using filler containing chloride as antifreeze, and hard aggregates and rubber chips as resin mortar. Furthermore, trial drainage pavements by using general materials with different mix design and new materials mentioned above were constructed and the performance in a snow season was investigated.

2. Introduction

Figure 1 shows a flowchart of the present study. This study is divided into two parts, that is, general materials in different mix design and new materials of drainage pavement. The laboratory tests and field tests were conducted in each material.

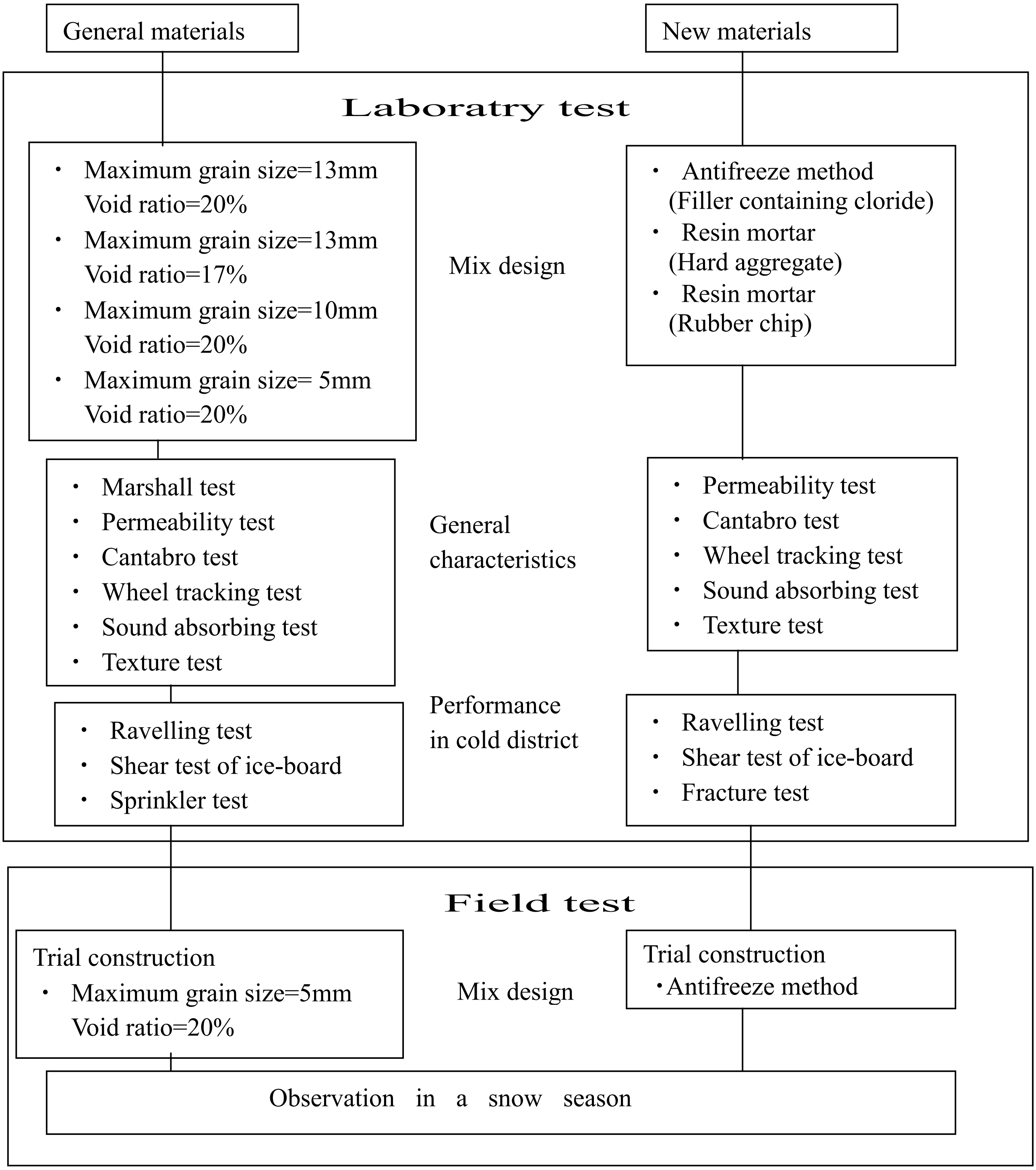


Fig.1 Flowchart of the study

3. Laboratory Tests of General Materials

3.1 Mixture ratio of general materials

The effects of maximum grain size and void ratio of the materials on performance of a drainage pavement was investigated. Four samples with different mixture ratio of materials were used in the tests. Table 1 lists the maximum grain size, void ratio and mixture ratio of each sample. “13mm20%” is a typical mix design in Japan. “13mm17%” is recommended for cold district by Japan Highway Public Corporation. No. 6 crushed stone was used to make the maximum grain size 10mm in “10mm20%” and No. 7 crushed stone was used to make the maximum grain size 5mm in “5mm20%”. The thickness of drainage pavement of “10mm20%” and “5mm20%” could be reduced to 30mm and 20mm, respectively. A general view of each sample is shown in Photo.1.

Table 1 Mix proportion of general materials.

Specified name		13mm20%	13mm17%	10mm20%	5mm20%
Maximum grain size(mm)		13	13	10	5
Void ratio(%)		20	17	20	20
Mix proportion(%)	No.6 crushed stone	85.0	80.0		
	Single-sized No.6 crushed stone10-			84.0	
	No.7 crushed stone				76.0
	Coarse sand	9.5	15.0	10.5	19.0
	Stone powder	5.5	5.0	5.5	5.0
	Plant fiber	0.1	0.1	0.1	0.1
High viscosity asphalt content(%)		5.3	5.5	5.1	5.0

(a)13mm20%

(b)13mm17%

(c)10mm20%

(d)5mm20%

Photo 1 General view of each sample(300mm×150mm)

3.2 Test procedure

Six types of test as shown in Table 2 were conducted to clarify general characteristics of each sample. Each test and its reference are listed in Table 2.

Table 2 Tests for general characteristics of general pavement.

Characteristics	Name of tests	References	Remarks
Strength	Marshall	Manual of pavement test	
Drainage-permeability	Premeability	Manual of pavement test	
Aggregate resistance	Cantabro	Manual of pavement test (separate volume)	Curing temperature 20℃,-20℃
Anti-flow	Wheel tracking	Manual of pavement test	
Sound absorbing	Sound absorbing	JIS A1405	
Roughness	Texture	Laser	

In addition, following three types of test were done to verify the required performance in cold district. The first test is ravelling test referred by a manual of pavement test. Wearing resistance due to tire chain is seems to be examined by this test. The second test is a shear test of ice-board. This test was conducted in a temperature of -10° C and loading speed was 1mm/min. A sample of 100mm x 100mm was attached on the ice board of 30mm thickness. Photo. 2 shows a view of this test.

Finally, sprinkler test was performed to clarify the effect of melting snow on a road. The sample with 2% of a slope that coincides with a transverse slope of actual road was sprinkled to check the water on the sample. Impermeable stratum was set on the bottom of the sample and volume of the sample was 150mm x 300mm x thickness in each case. The sprinkled water was measured volume when enough water for melting snow remained on the surface of sample. Photo.3 shows a view of this test.

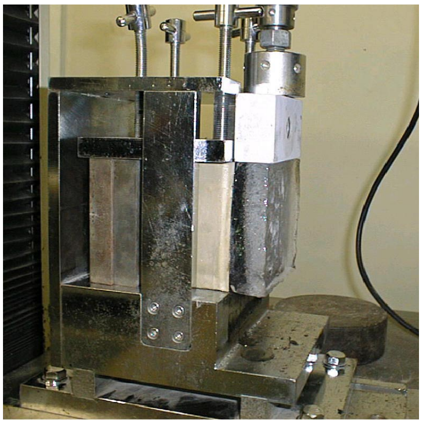


Photo 2
View of shear test of ice-board

Photo 3
View of sprinkler test

3.3 Test results and discussions

The results of laboratory tests are listed in Table 3.

Table 3 Test results of general materials.

		Standard		Small void ratio		Small grain size, thin				Target values in the special specification
Specified name		13mm20%		13mm17%		10mm20%		5mm20%		
Standard thickness (mm)		40		40		30		20		
Marshall stability(kN)		6.88	○	6.19	○	6.16	○	6.55	○	Over 3.5
Coefficient of permeability k15 (cm/s)		3.37×10^{-1}	○	1.31×10^{-1}	○	2.71×10^{-1}	○	7.00×10^{-2}	△	Over 10^{-2}
Cantabro loss(%)	20℃	6.9	○	4.3	◎	6.4	○	5.8	◎	
	−20℃	19.6	○	12.1	◎	21.4	○	14.7	◎	
Dynamic stability(cycle/mm)		10200	○	6200	○	7600	○	7900	○	B trafic:over 1500 A trafic:over 3000
Average sound absorbing ratio for the perpendicular incident on the board		0.23	○	0.17	△	0.27	○	0.33	◎	
Standard deviation of surface texture(mm)		1.93	—	1.52	—	1.42	—	0.57	—	
Ravelling abrasion (cm^2)	Side chain, −10℃	0.91	○	0.93	○	1.12	△	1.37	△	
Shear strength of ice-board(N/mm^2)	−10℃	0.52	○	0.47	◎	0.52	○	0.65	△	
Water volume for accumulating at surface of sample(cc/min.)		98	○	83	○	118	○	19	◎	

Evaluation : ◎Superior ○Same △Inferior ×Under the value of the special specification

The following findings are drawn from the table.

1) The results of all samples satisfied the target values of the special specification.
2) Since the average sound absorbing ratio of "13mm17%" is less than that of "13mm20%" which is a case of typical mix design , the effect of reducing traffic noise seems to be smaller. However, the aggregate resistance and hard removal of compressed snow on a road seem to be improved because that the Cantabro loss and ice-board shear strength of "13mm17%" are smaller than those of the typical mix design.
3) The characteristics of "10mm20%" are similar to those of the typical mix design .
4) Although the permeability, anti-frictional wear and removal of compressed snow on a road of "5mm20%" are inferior to those of the typical mix design , effects of reducing traffic noise and water spray to melt snow are improved.

4. Laboratory Tests of New Materials

4.1 Introduction of new materials

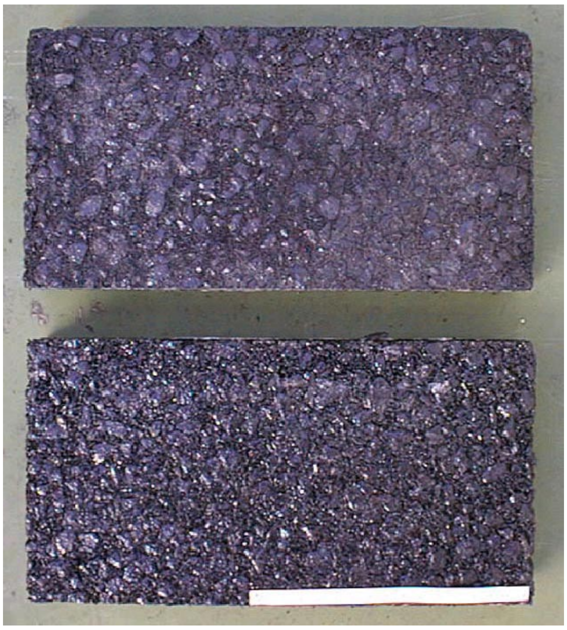
As problems to be solved, blocking a void of pavement with earth and sand, crushing the void by a weight of automobile, scattering of an aggregate at an intersection of road, etc. are pointed out. Maintenance in a snow season such as snow removal on a road and scattering of antifreeze should be also considered simultaneously with the problems mentioned above in a cold district such as Ishikawa Prefecture. Therefore, new materials were examined to solve the problems in this chapter. One of them is filler containing chloride. This is used for high-density asphalt concrete as antifreeze. A possibility of its application to a drainage pavement was studied here. Other is a resin mortar that includes a hard aggregate or rubber chip. Effects of strengthening of road surface and a physical antifreeze effect of the resin mortar were examined. Tables 4 and 5 list mixture ratios of filler containing chloride and resin mortar, respectively. A general view of each sample is shown in Photo.4.

Table 4 Mix proportion of new materials using antifreeze.

Mix proportion (%)	No.6 crushed stone	85.0
	Coarse sand	9.5
	Antifreeze	4.7
	Plant fiber	0.1
	High viscosity asphalt	5.3

Table 5 Mix proportion of new materials using resin mortar.

		Hard aggregate	Rubber chip
Mix proportion (%)	Epoxy resin Resin:Hardener=2:1	15vol%	20vol%
	Hard aggregate / Rubber chip	100	



(a)Resin mortar(Hard aggregate)

(b) Resin mortar(Rubber chip)

Photo 4 View of drainage pavement using resin mortar(300mm×150mm)

4.2 Test procedure

Five types of test as shown in Table 2 were conducted to clarify general characteristics of each sample. Marshall test was omitted here. In addition, following three types of test were performed to verify the requirement performance in cold district. The ravelling tests and shear tests of ice-board are same as those mentioned before. Final test is fracture test of ice-board. A wheel travels on a sample for the wheel tracking test with ice board of 3mm in thickness and the change of surface condition was observed visually. Photo.5 shows a view of this test.

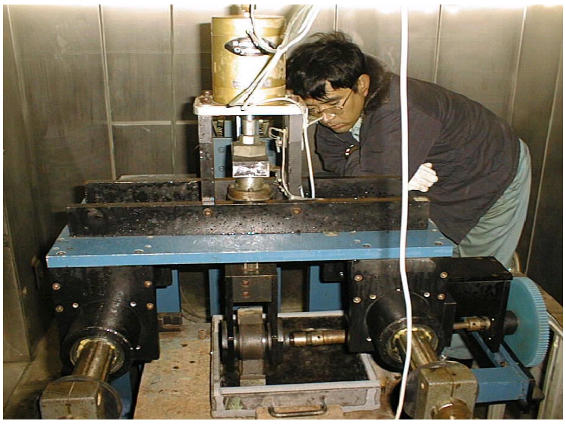


Photo 5 View of fracture test of ice-board

4.3 Test results and discussions

The results of laboratory tests are listed in Table 6.

Table 6 Test results of new materials.

Specified name		Drainage		Antifreeze		Resin (Aggregate)		Resin (Rubber)		Target values in the special specification
		13mm20%		13mm20%						
Standard thickness (mm)		40		40		40		40		
Marshall stability(kN)		6.88	○	—	—	—	—	—	—	Over 3.5
Coefficient of permeability k15 (cm/s)		3.37×10^{-1}	○	2.74×10^{-1}	○	2.11×10^{-1}	○	2.09×10^{-1}	○	Over 10^{-2}
Cantabro loss(%)	20℃	6.9	○	7.0	○	—	—	—	—	—
	−20℃	19.6	○	20.0	○	—	—	—	—	—
Dynamic stability(cycle/mm)		10200	○	10800	○	8300	○	8300	○	B trafic:over 1500 A trafic:over 3000
Average sound absorbing ratio for the perpendicular incident on the board		0.22	○	—		0.23	○	0.19	○	—
Standard deviation of surface texture(mm)		1.93	—	—	—	0.79	—	0.64	—	—
Ravelling abrasion (cm^2)	Side chain, −10℃	0.91	○	0.79	○	0.37	◎	0.74	◎	—
Shear strength of ice-board(N/mm^2)	−10℃	0.52	○	0.31	◎	0.32	◎	0.34	◎	—
Condition of ice layer after wheel loading		No change	○	Melt	◎	No change	○	Crack	◎	—

Evaluation : ◎Superior ○Same △Inferior ×Under the value of the special specification

The following findings are drawn from the table.

1) The results of all samples satisfied the target values of the special specification. The general characteristics of sample with new materials are not inferior to those of the general materials.
2) Since the surface of ice-board with antifreeze melted in fracture test, the drainage pavement with antifreeze seems to be advantageous in the cold district. This is called as chemical antifreeze effect of chloride in this paper.
3) The ravelling abrasion and ice-board shear strength of samples with resin mortar are superior to those of the general materials. The resin mortar, therefore, seems to improve freezing and frictional wear due to tire chain.
4) The loading of automobile can fracture an ice on the surface of pavement with resin mortar of rubber chip. In this paper, this is called physical antifreeze effect of rubber chip .

5. Field Tests

Trial constructions by using general materials with small grain size and new materials were done in a field. First, the drainage pavement of “5mm20%” was constructed. The thickness of the drainage pavement was 20mm. Coarse materials with 20mm of maximum grain size were laid under the drainage pavement. Its thickness was 70mm. Length of the road was 60m and its width was 7m. The result of permeability test in the field was 1003ml/15sec. This road has installation of water spraying from a water pipe under the road to melt snow . Photo.6 shows the condition of roads with the drainage pavement of “13mm20%” and “5mm20%” in snow season. According to this photograph, there is more water on the road with the drainage pavement than that with the general pavement and white lines are visible in case of the drainage pavement. The effects of water spray to melt snow on the drainage pavement were, therefore, verified.

(a)Drainage pavement of “5mm20%”
(2001.2.15 7:00am)

(b)Drainage pavement of “13mm20%”
(2001.2.15 7:00am)

Photo 6 Road condition of drainage pavement of “5mm20%”and “13mm20%”

Next, the drainage pavement with antifreeze instead of stone powder was constructed. The thickness of the drainage pavement was 40mm. Coarse materials with 20mm of maximum grain size were laid under the drainage pavement. Its thickness was 70mm. Length of the road was 60m and its width was 6m. The result of permeability test in the field was 1039ml/15sec. Photo.7 shows the condition of roads with the drainage pavement with antifreeze and with typical mix design in snow season. According to this photograph, there is no substantial difference between two types of pavements, but the compressed snow on the drainage pavement is somewhat soft.

(a)Drainage pavement with antifreeze
(2001.2.15 0:00am)

(b)Drainage pavement of "13mm20%"
(2001.2.15 0:00am)

Photo 7 Road condition of drainage pavement with antifreeze and with typical mix design

6. Concluding Remarks

This paper focused on the structure of drainage pavement in a cold district. Effects of maximum grain size and void ratio of materials on permeability of a pavement and the performance in a snow season were investigated and new materials of a drainage pavement were examined in a laboratory. Trial drainage pavements by using general materials with different mix design and new materials were constructed and the performance in a snow season was investigated. The following conclusions may be drawn from the study.

In case of general materials with 5mm of maximum grain size, effects of reducing traffic noise and water spray to melt snow were improved, although the permeability, wearing resistance and removal of compressed snow on a road were inferior to those of the typical mix design. The permeability, however, satisfied the target values shown in Technical Guideline of Drainage Pavement (Draft) issued by Japan Road Association and Special Specification of Drainage Pavement issued by Ishikawa prefectural government. The effects of water spray to melt snow on the drainage pavement were also verified in the field tests. Since the initial cost of a pavement could be reduced because the thickness of pavement became small in this case, further study should be continued.

The new materials proposed here showed good performance under the circumstances in the cold district. The drainage pavement with antifreeze seems to be advantageous in the cold district because the chemical antifreeze effect of chloride was verified. The resin mortar seems to improve freezing and wearing resistance due to tire chain. The loading of automobile can fracture the ice on the surface of pavement with resin mortar of rubber chips. The physical antifreeze effect of rubber chip was verified in this paper.

Further study is needed on new materials, an optimum mixture ratio, aging effects of the trial construction and so on. Cost performance from the point of the total cost should be considered in the future.

Reference

1) Makoto, TAMAKI: Road Maintenance in winter and Pavement Technology in Hokuriku Regional Construction Bureau, Pavement Vol. 3, No. 9, 2000.