FUNCTIONAL RECOVERABLE FREEZE-PREVENTING PAVEMENT

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1.Abstract

There have been various contrived methods in use for preventing the pavement surface from freezing in cold snowy areas.Road heating systems are certainly effective. But it is very expensive for construction and maintenance.Other methods adopted, for example, are an asphalt mix incorporated with a salt, (i.e., salt-like material such as calcium chloride) and with an elastomer such as rubber.

The salt-containing pavement becomes ineffective after one to two years because of leaching out of the salt.

The elastomer in the pavement tends to come out in summer on account of its low combined strength in general. And the pavement tends to be rutted in summer.

It is important that the pavement maintains the freeze-preventing effect over a long period of time and can restore when its effect has been lost.

The functional recoverable freeze-preventing surface course that has such functions has been newly developed and has been in practical use.

The paper describes the result of the 3-years field test and the improvement for its durability and effectiveness.

2.Introduction

The Freeze-Preventing Pavement is a thin layer of open graded asphalt mixture whose voids are grouted with cement slurry comprising portland cement, specific salt, and superabsorbent polymer. (shown in Fig. 1)

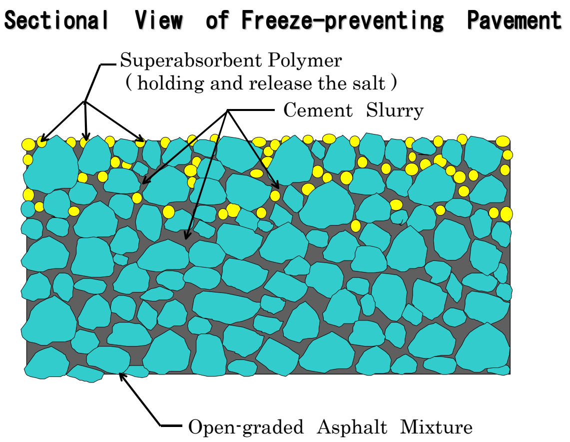

Fig. 1 Sectional View of Freeze-preventing Pavement

The salt is diluted in form of aqueous solution, which is to be absorbed into the polymer in large amount.

The polymer in the slurry holding the salt solution infiltrates into the voids of the surface course.

The salt in the polymer gradually oozes out on to the pavement surface and makes it easy to tear off the ice on the pavement.

The effect is maintained for a long period of time owing to the polymer which can absorb, retain and release the salt solution continually.

The freeze-preventing effect can also be restored and maintained by spraying the salt solution on the surface periodically.

3.Materials

3.1.The Superabsorbent polymer

The superabsorbent polymer previously mentioned is poly N-vinyl acetamide (PNVA: developed by SHOWA DENKO K.K.), which can absorb high concentrated salt solution. The conventional high water absorbent polymers such as poli-acrylic polymer used for diapers, for example, can not absorb and discharge water repeatedly. However, the PNVA that was developed and succeeded in synthesizing in 1995 by Showa Denko K.K., a Japanese chemical manufacturer, has characteristics of stabilized repetitive absorption and discharge of water. The PNVA is also considered to be suitable even for greening deserts by plantation, because it has excellent resistance to weathering and do not disassemble in several months not like other conventional polymers. In addition, the PNVA absorbs water or solution without being influenced by ions dissolved in water, because it is a non-ion material that does not have the ion base in its molecular structure.(1)

PNVA has been improved to solve the construction problem. There was sometimes such a case that sufficient filling was not done, because the expansion rate of PNVA was too high for cement slurry to infiltrate into the open-graded asphalt mixture.

Therefore, the sufficient strength of the pavement was obtained and the pavement was damaged at early stages due to the lack of sufficient resistance to freezing and thawing.

The expansion rate of PNVA was deduced and the new PNVA does not expand for about 20 minutes by hydrophobic coating on it.

3.2.The Salt

The salts that can be used are inorganic salts such as calcium chloride, potassium chloride and organic salts such as potassium acetate, calcium acetate, magnesium acetate, and sodium propionate.

Of these examples, an acetate such as potassium acetate is preferable because it lowers greater freezing point than calcium chloride. Therefore, it produces better freeze-preventing effect at low temperatures. In addition, it gives little influence on the strength of portland cement mortal, and it is less corrosive to iron and other metals.

3.3.Cement slurry

The mix formula for cement slurry was made taking into consideration the ability of salt solution retaining, durability, and workability. The fluidity of cement slurry including PNVA is evaluated by the flow value measured by P type Funnel Method.

The cement slurry can be grouted smoothly when its flow value is in the range of 9 to 12 seconds.

The portland cement used for this method shall be super rapid setting cement because the PNVA will absorb salt solution and swell to its maximum in the cement slurry within two hours and too much polymers tend to gather to the pavement surface due to the buoyancy and get out of the pavement. Therefore, the above-mentioned cement capable of setting within one hour shall be used.

The super rapid setting cement is used as a form of pre-packed cement compound. The super rapid setting cement and silica sand and acrylic emulsion are mixed. Furthermore, black carbon pigment is added and mixed in order to hasten melting of snow during daytime.

3.4.Open graded asphalt mixture

The aggregate particle size distribution for open graded asphalt mixture is shown in table-1. This has been determined considering the durability in the cold regions. At the early stages the air voids from 22 to 23% was specified because the expansion rate of PNVA is high. However, the pavement air voids from 15 to 21% is now specified due to the improvement of expansion late. Also, the asphalt is specified to use the high viscosity modified asphalt. This is because the damages at early stages in the cold areas should be avoided.

The standard values for Marshall Test Method are shown in table-2.
It is especially important that the loss value by Cantabro Test at -20℃ is 20% or less.

Table-1 : Percent passing of aggregates for open graded asphalt mixture

Maximum size (mm)	Sieve sizes (mm)							
	19.0	13.2	4.75	2.36	0.600	0.300	0.150	0.075
13	100 (%)	92～100	9～31	9～21	4～17	3～12	3～8	2～7

Table-2 : The standard values of Marshall Test Method

Item	Standard value of Marshall Method
Density (g/cm^3)	1.90 or more
Stability (KN)	4.90 or more
Flow value (1/100cm)	20～40
Air voids (%)	15～21
Asphalt(*) content (%)	4.5～5.5
CantabroTest(at -20℃)	20% or less

(*) High viscosity modified asphalt

4.Properties

An example of the properties of the cement slurry containing PNVA and Freeze-Preventing Pavement is shown in table-3. The typical properties are almost equal to those of semi-flexible pavement.[2] But skid resistance number (BPN at 20℃) is higher than that of semi-flexible pavement (typical value is from 50 to 60). Because the semi-flexible pavement tends to bleed just after grouted with cement slurry. However, this method of construction will not produce bleeding on account of the polymer.

Table-3 : Properties of the cement slurry including PNVA and Freeze-Preventing Pavement

	Item	Value	JRA standard value of semi-flexible pavement	Test Method
Cement Slurry including PNVA	Flow value by P-type (sec.)	10.0	10～14	JIS R 5201
	Compressive strength at 7days (N/mm^2)	27.8	9.8～29.4	JIS R 5201
	Bending strength at 7days (N/mm^2)	5.7	2.0 or more	JIS R 5201
Freeze-Preventing-Pavement	Item	Value	Standard value of semi-flexible pavement	Test Method
	Bending strength (N/mm^2)	2.5	1.8(Met.Expressway spec.)	JRA Test Method (20℃、7days)
	Dynamic stability (Number /mm)	20, 000	—	(60℃、0.68KN、42Number/min.)
	Wearing quantity by ravelling test(cm^2)	0.82	—	(-10℃、Cross chain used)
	Skid resistance (BPN)	65	60 or more (JH spec.)	ASTM E 303 (20℃)

*JRA Japan Road Association

*JH Japan Highway Public Corporation

5.Durability by the freezing and thawing test

The durability of the Freeze-Preventing Pavement in the cold regions was checked and tested by doing 150 cycles of freezing at –20℃ and thawing at 10℃. Before the freezing and thawing test, all the salt in the specimen was removed. After freezing and thawing on the specimen, the chain ravelling test (cross chain used: testing temperature -10℃: duration 90minutes) and the low temperature Cantabro test (testing temperature-20℃: 300 rotations) .

Three types of asphalt mixture (i.e. open-graded asphalt mixture with high viscosity modified asphalt, Freeze-Preventing Pavement before improved and after improved) are tested for comparison. The test results are shown in Fig. 2 and Fig. 3.

Fig. 2 shows the result of a chain ravelling test. This figure is showing that there is no difference before and after improved pavement. A good result is also shown compared with the open-graded asphalt mixture. However, there was a damage at early stage in the test field of the cold regions before improvement of pavement. This is considered that the durability between them is different.

The cantabro test result shows the difference between them. The improved pavement shows that the cantabro loss is decreased to about half of that in open-graded asphalt mixture and the improvement is obviously.

It can be confirmed that the resistance to the scattering of the aggregate in winter was improved .

Also, from this result, It is considered that there will be a problem as to the durability of open-graded asphalt mixture in the cold regions.

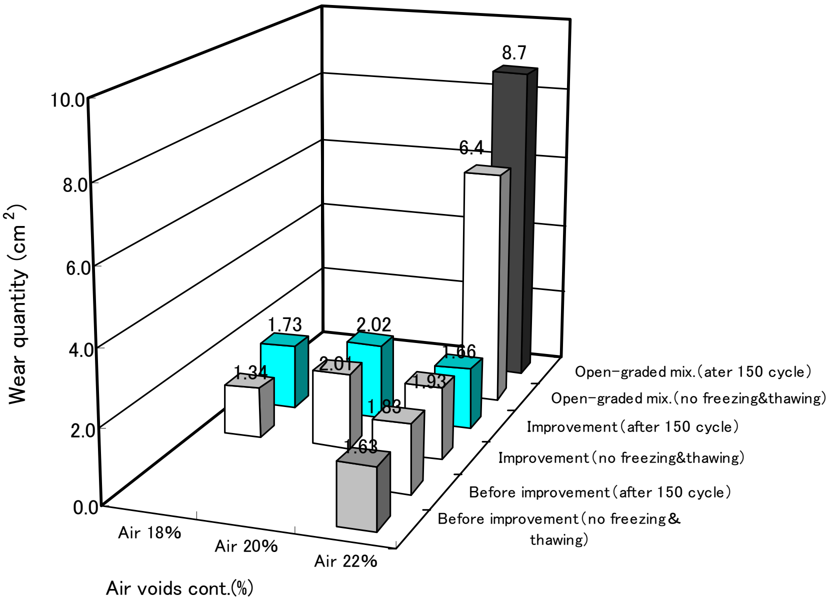

Fig.2 After thaws and freezes Ｒavelling test result

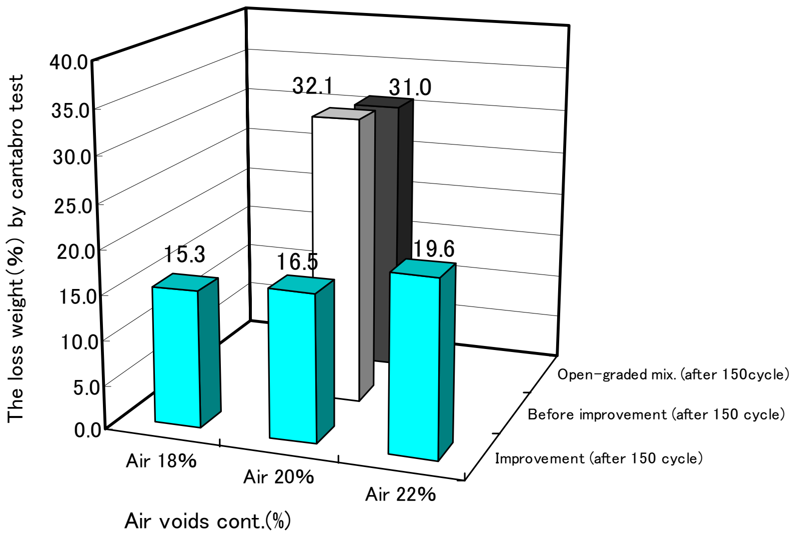

Fig.3 Low temperature Cantabro test result after freezing and thawing

6. Ice adhesive strength tests

In Fig. 4, ice adhesive strength is plotted against temperature. It is apparent from Fig. 4 that the ice adhesive strength of the freeze-preventing pavement (regardless of salt content) is about 1/7 at -5℃, 1/4 at -10℃ and 1/2 at -15℃, respectively, of that of conventional pavements, concrete, asphalt , and semi-flexible pavement.

The ice adhesive strength shows that the ice covering the pavement is easily torn off by traffic loads.

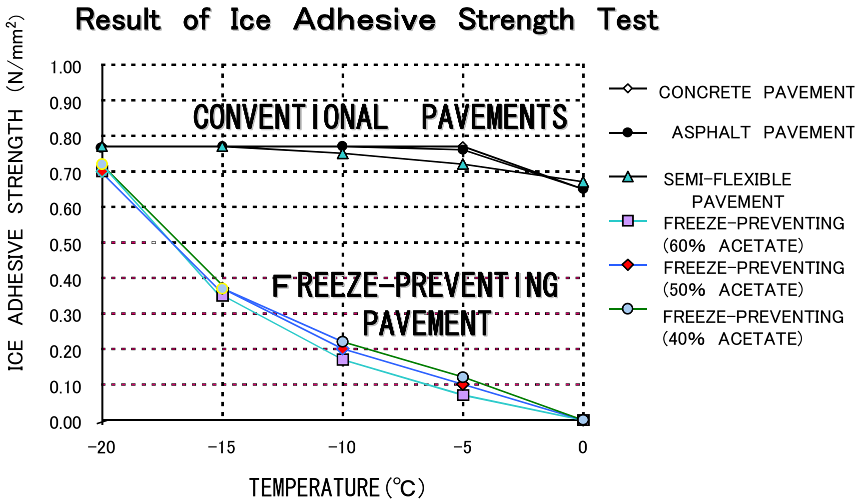

Fig.4 Result of ice adhesive strength

The outline of the test device is shown in figure-5. Also, The test was performed in conformity with the method by the Research Group for Anti-icing Pavements in Japan.[3]

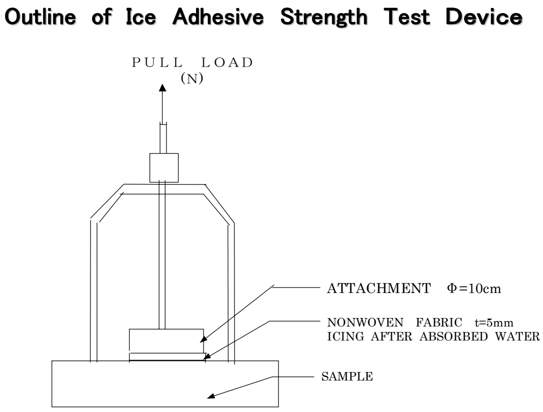

Fig.5 Ice adhesive strength test device

7.Rrepeated tests

Fig.6 graphically shows the result of repeated tests for ice adhesive strength of the freeze-preventing pavement.

Ice adhesive strength is plotted against the number of icing tests which were repeated at -10℃. It is apparent from Fig. 6 that the ice adhesive strength of the freeze-preventing pavement (regardless of salt content) tends to increase gradually as the icing test is repeated. When the ice adhesive strength had reached the maximum value of about 0.25 N/mm^2, the salt was sprayed on the freeze-preventing pavement.
The ice adhesive strength sharply decreased to about 0.1 N/mm^2, presumably, owing to the salt remaining on the pavement surface. After repeated icing tests, the ice adhesive strength gradually approached about 0.25 N/mm^2.

This suggests that the freeze-preventing effect is restored when the salt is sprayed on the pavement.

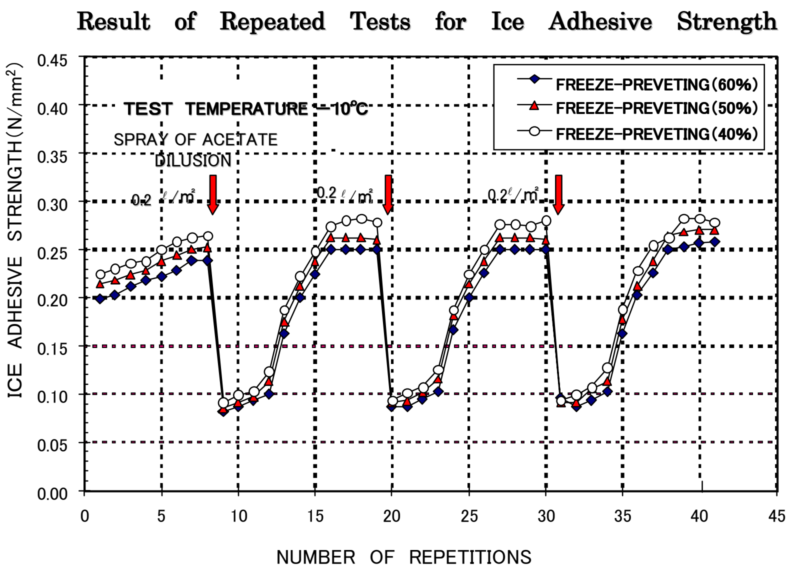

Fig.6 Result of repeated test for ice adhesive strength

8.Field Test Results

Fig. 7 graphically presents the field test result on the remained salt on the freeze-preventing pavement measured by refraction method. (Measurement was performed on the sprayed water on the surface with 2m ℓ/100cm^2)

The pavement becomes ineffective after three months or so because of leaching out of the salt.

However, the salt content can recover for the 3 years of measurement, even tough the capability trend is decreasing. There might be the possibility that it does not recover after 6 or 5 years according to this trend.

It is assured that 1.2% of the low salt content is effective at -5℃ in the HOKKAIDO Pref.

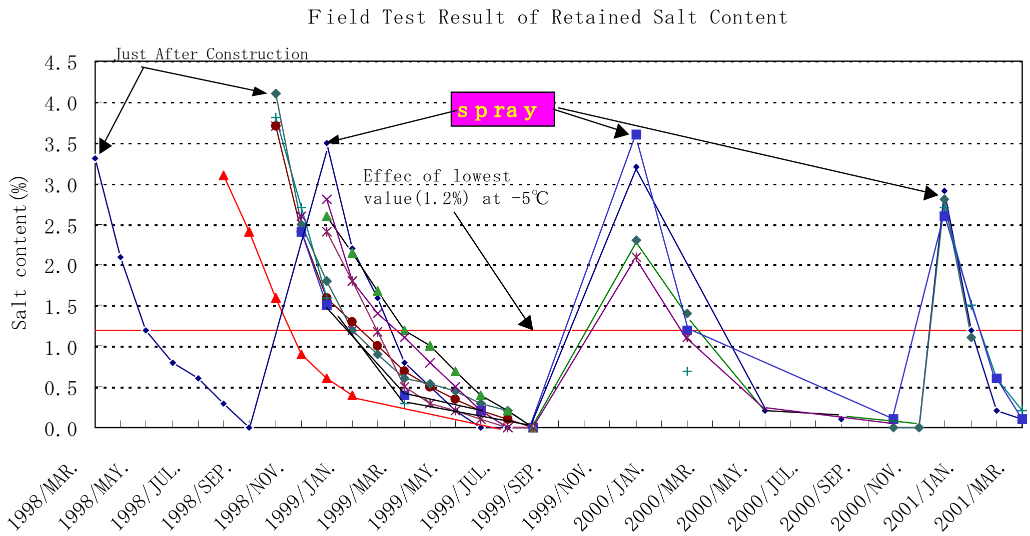

Fig.7　Field Test Result of Retained Salt Content

Fig. 8 shows the field test result of the retained salt content on the original pavement and the restored pavement when the pavement is sprayed with 50% of potassium acetate content solution.

By spraying salt on the pavement surface periodically, the effect can be maintained for a long period of time (may be as long as 5 years or more) owing to the polymer, which can absorb, retain and release the salt.

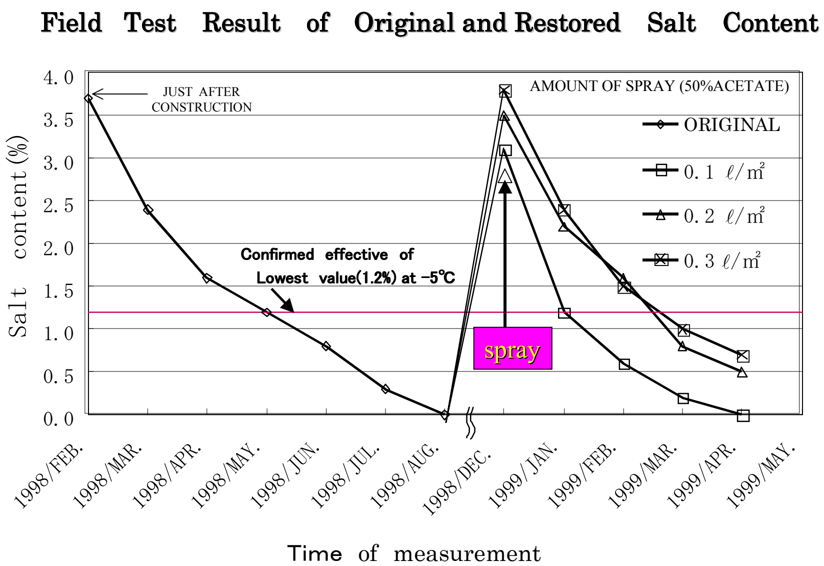

Fig.8 Field Test Result of Original and Restored Salt Content

This field test shows that it tends to rapidly leach out the salt in case of 0.1 ℓ/㎡.
But, by spraying 0.2 ℓ/㎡ or more , it tends to slowly leach out. Consequently, spraying 0.2 ℓ/㎡ or more is preferable .

The freeze-preventing effects are shown in Photo 1. The photograph was taken in March, 2001 at -5℃, in the test field which was constructed in October, 2000 in Iwate Pref., and the effect was confirmed. This field was constructed with the improved pavement mixture and there have not been any problem.

Phot-1. IWATE Pref. （taken in March,2001: at –5℃）

Durability is shown in Photo 2. This pavement was constructed on the concrete bridge with the improved pavement in December, 2000. This site is located at 44° 30′ N in Hokkaido in the coldest area of Japan. The lowest temperature is less than -20℃ in winter and snowfall is heavy

The durability was confirmed even in this severe site.

Phot-2. HOKKAIDO Pref. （taken in April 2001）

9.Conclusions

Understandings from the result of the observation for 3 years are as follows;.

(1) The high viscosity modified asphalt should be used for open-graded asphalt mixture in severe cold regions. The pavement would be damaged at early stage, if it is not used.
(2) The durability test should be done in severe cold regions with the low temperature Cantabro test after freezing and thawing.
(3) The freeze-preventing is effective at 1.2% of salt content and it was confirmed to –5℃.
(4) The recovery of the salt content is assured even though the trend gradually lessens.
The freeze-preventing effect can be confirmed for 3 years.
(5) Field test result shows that the improved freeze-preventing pavement does not have any defective influences on pavement performance, such as, rutting, ravelling, cracking, structural failures, etc..

The performance of the Freeze-Preventing Pavement should ,however, be observed further so that the effectiveness and durability of this method can be confirmed.

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