FOLLOW-UP SURVEY OF PERMEABLE INTERLOCKING BLOCKS APPLIED TO THE ROADWAY IN COLD, SNOWY AREAS

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ABSTRACT

Ichibanboridoricho honcho Line in Niigata City, which is a cold, snowy area, has just begun to be developed into a community street that gives first priority to pedestrians.
This thesis will report on the characteristics of the interlocking blocks applied to the street and the surface conditions after the construction.
In order to harmonize of the street to the landscape and the environment, permeable interlocking blocks were applied to both the roadway and the sidewalks. For the roadway the blinder course was made with open-graded asphalt concrete and wave-shaped rectangular blocks covered the surface. The sidewalks were covered with permeable interlocking blocks that were polished on the surface and were in the large-sized straight type for harmonization with the landscape.
It was supposed that the permeability and the durability of the interlocking blocks would decline under the weather conditions of the cold, snowy area. But the follow-up survey conducted one year after the construction shows the following good conditions of the road surface;
(1) The blocks were not damaged. The grades of unevenness, skid resistance and flexure was good.
(2) The joint spacing had changed a little due to the weight of the running vehicles, but the joint lines were still straight.
(3) The Permeability of the sidewalks had reduced, but the permeability of the wheel path was in good condition.
As a result we conclude that covering the road with permeable interlocking blocks is a quite effective paving method in term of the harmonizing with the landscape and the environment under the certain condition of the blinder course and the traffic.

1. INTRODUCTION

The social requirements for pavements used to focus on vehicle traffic, but the "harmonization of the pavements to the humans and the environment", and the landscape are today gaining importance in the planning of pavements.

In Niigata City, the network for pedestrians has been established through the walking trail project and the comprehensive plan of the road system is being carried out. In the walking trail project the pedestrian roads start from the traffic centers, such as the station and the bus terminals, and pass by the cultural and historical spots in the city. On the roads people can enjoy the scenery of the Shinano River, the symbol of the city, the beautiful sun set on the Japan Sea and experience the prosperity of the main streets and the atmosphere of down town.

Ichibanboridoricho honcho Line is one of the main streets of the city and is a part of the project. It has begun to be developed into a community street that gives first priority to pedestrians. One of the characteristics of the development is that the roadway and the sidewalks are covered by two types of interlocking blocks; the permeable interlocking blocks and the polished permeable interlocking blocks (i.e. its surface is polished.). In the planning, the harmonization of the block color to the landscape was examined using computer graphics and also, the splashing of the pedestrians and the consideration of the inhabitants along the street were taken into account. But in a cold, snowy area such as Niigata City, the deterioration of the strength of the blocks through repeated freeze and melt and the damage to the corners of the blocks through the snow clearing work were feared.

This thesis will report about the characteristics of the interlocking blocks, their application and the follow-up survey.

2. THE OUTLINE OF THE ICHBANBORIDORICHO HONCHO LINE

The Central Park of Niigata City consists of Hakusan Park and the Niigata City Performing Arts Center. The center was recently completed on the bank of the Shinano River, as the base for the cultural activities of the citizens. The Ichibanboridoricho honcho Line connects the Central Park and the Furumachi District- the business and shopping center of Niigata City. Along the street there are lots of traditional houses.

Table 1 shows the meteorological data. Niigata City has sometimes over 20-cm of snow on the ground in winter and is a cold, snowy area.

Table 1. The meteorological data

ITEM	1998.12	1999.1	1999.2	1999.3
The average temperature (°C)	6.3	3.1	2.6	6.7
The duration where snow stay on the ground (day)	0	10	8	0
The maximum snowfall (cm)	0	38	29	0

3. THE CHARACTERISTICS OF THE PERMEABLE INTERLOCKING BLOCKS

3.1 THE CHARACTERISTICS OF THE PERMEABLE INTERLOCKING BLOCKS

The Characteristics of permeable interlocking blocks are as follows;

(1) Rainwater permeates into the blocks and it avoids puddle formation on the road.
(2) The blocks are in a light color and retain humidity, so that the surface of the blocks is cooler than the surface of the asphalt pavement.
(3) The many holes on the surface reduce the noise of running tires.

Especially in the high temperature in summer lots of water evaporates from the blocks and the temperature of the surface of the pavement stays cooler than that of asphalt pavement, as shown in Figure 1. In winter time the rainwater stays in the base course and works as a heat retainer, so that the pavement stays warmer. Thus the blocks have the effect of improving the environment.
Dirt hardly sticks on the polished blocks of the sidewalks. They stay clean. The color of the block is also chosen in order to harmonize to the landscape.

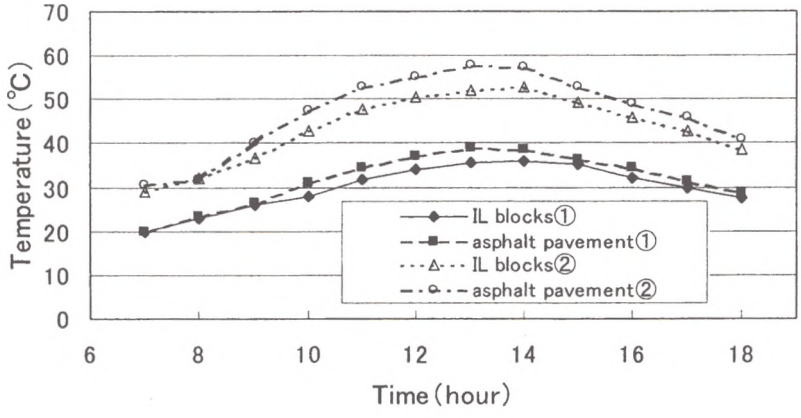

Figure 1. The temperature of the pavement surface

3.2 THE TECHNICAL CHARACTERISTICS OF THE PERMEABLE INTERLOCKING BLOCKS

Figure 2 shows the technical characteristics of the impermeable interlocking blocks and the permeable interlocking blocks used for the roadway and sidewalks.
In comparison with the usual permeable interlocking blocks, the polished permeable interlocking blocks are not different in their strength and skid resistance, but have a bigger permeability coefficient. It comes from the differences in the size of the grains of the aggregate. The grains of the usual permeable interlocking blocks are between 0 to 2.5 mm, but the grains of the polished permeable interlocking blocks are single sized and they are between 2.5 to 5 mm. We chose the polished ones to facilitate more comfortable walking.

Table 2. The technical characteristics

ITEM	Impermeable IL blocks	Permeable IL blocks		Method of the test
		Standerd	Polished	
Bending strength (N/mm^2)	6.22	4.07	3.89	Loading in the center
Coefficient of permeable (cm/sec)	—	3.33×10^{-2}	8.50×10^{-2}	Constant head permeable test
Skid resistance	71	79	72	ASTM E303
Void (%)	—	13	15	
Mearing resistance (mm/1,000times)	0.60	0.80	0.83	JIS A 1451

3.3 THE DURABILITY OF THE PERMEABLE INTERLOCKING BLOCKS

For applying the permeable interlocking blocks to the roadway, there are problems in moving and damage to the corners of the blocks. But the other experiments that were already undertaken show that there are ways to ease these problems.

3.3.1 THE LAY PATTERN AND THE MOVEMENT OF THE BLOCKS

To find the best lay pattern that allows the blocks the least movement, we drove a wheel of 7-ton weight on the blocks in the open and measured the distance between two blocks. Figure 2 shows the length of the movement according to the patterns, stretcher bond and herringbone bond bond.

According to Figure 2, the length of the movement of herringbone bond is smaller than that of stretcher bond. Therefore the lay pattern of the permeable interlocking blocks for the roadway pavement should be herringbone.

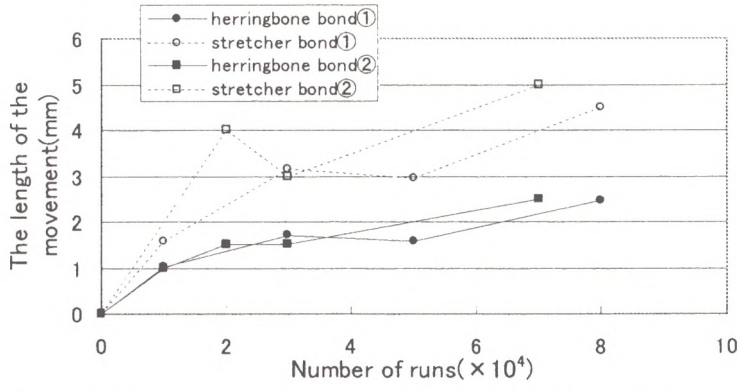

Figure 2.Amounts of the movement according to the various pattern

3.3.2 THE EVALUTATION OF THE DURABILITY IN THE ROAD SIMULATION

We undertook the running examination by the road simulator in order to verify the durability against the damages to the block corners caused by the traffic. Thanks to the simulation in the open, we could evaluate the effects of the varied load on the pavements under very similar conditions to reality.

Table 3 shows the test conditions, the Table 4 the terms of the evaluation and the Figure 3-4

the profile of the tested pavements.

According to the results in Table 5, there aren't big differences between the impermeable interlocking blocks and the permeable interlocking blocks in terms of flexure. There was no observation of the damages and cracks of the blocks. The bearing capacity factor of the both types of block in the plate bearing test increased 1.3 times after 1000 time loading.

Although the bending strength and the mearing resistance of each permeable interlocking block are inferior to the impermeable interlocking block, but the pavement as whole has enough bearing power against the traffic of commercial vehicles and therefore it is as applicable as the pavement made of impermeable interlocking blocks.

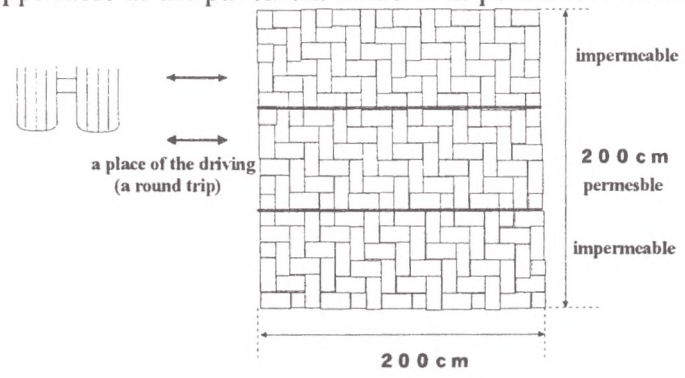

Figure 3.The laying pattern of the blocks at the with the road simulator

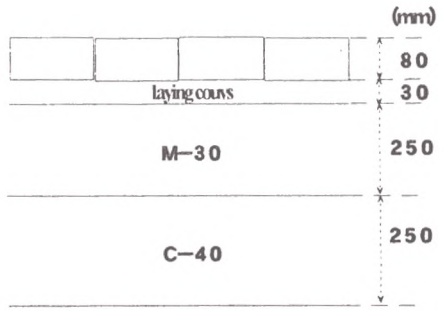

Figure 4.The structure of the pavement at the with the road simulator

Table 3. The test condiotion

The lay pattern	Herringbone bond 90°
The size of the construction	2m×2m=4m^2
Wheels load	5t
The direction of the moving load	a round trip
Travel speed	5km/h

Table 4. The terms of the evalutation

ITEM OF THE EVALUTATION	THE MEASURENENT FREQUENCY
Measuring Deflectin Using Benkelman-beam	Before and at the 1000 times driving
The conditions of the damages to the blocks	0,100,300,500,1000 times driving
Plate bearing test	Before and at the 1000 times driving

Table 5. The resulte of road simulator

ITEM OF THE TEST	The intial value		1000 time loading	
	Impermeable	Permeable	Impermeable	Permeable
Flexure (mm)	1.190	1.151	1.178	1.119
K30-value (kN/m^3)	392000	354760	50274	47216
The distress of blocks (pieces/m^2)	0	0	0	0

4.THE OUTLINE OF THE CONSTRUCTION OF ICHBANBORIDORICHO HONCHO LINE

Table 6 shows the outline of the construction.

Table 6. The outline of the construction

ITEM	CONTENTS
The name of the construction	Ichibanboridoricho honchodori line
The place of the construction	From Icibancho to Nibancho,Honchodori,Niigata city
The width of the costruction	9.5～11.5m
The extension of the construction	260.0m

4.1 THE FORM OF BLOCKS

The large blocks are used for the sidewalks, because the form is simple and there are a smaller number of joints. Walking on it is more comfortable. The waveform blocks are used for the roadway, so that the joints are tight.

4.2 THE LAY PATTERN

The lay pattern is stretcher bond for the sidewalks and herringbone bond 90° for the roadway, because it has a better load dispersion effect and the blocks in the pattern move less. This better load dispersion effect is achieved by the tighter joints of the blocks.

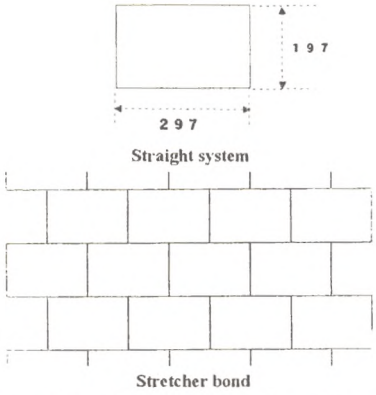

Figure 5.The lay pattern of the sidewalks

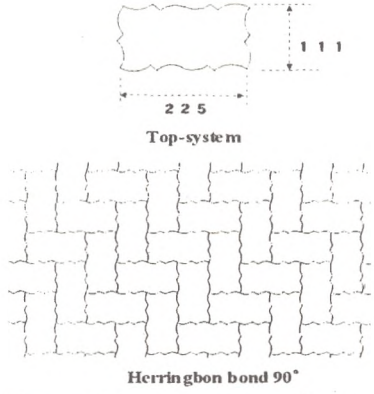

Figure 6.The lay pattern of the roadway

4.3 THE DESIGN OF THE PAVEMENT

This street has rather little traffic and is seen as a part of the road system for pedestrians. The boundary between the roadway and the sidewalks was marked by a flat white line in order to sure the safety of the pedestrians and the convenience of the inhabitants. (Figure 7) The line is formed by the white blocks. The white meandering line also causes drivers to drive slower.

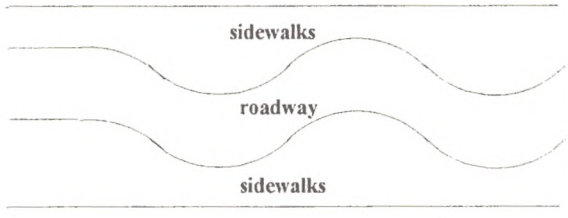

Figure 7.The alignment of the pavement

4.4 THE STURUCTURE OF THE PAVEMENT

Figure 8 and 9 show the structures of the roadway and the sidewalks. Especially for the roadway the binder course was constructed with the open-graded asphalt concrete that is permeable. Through this the structure became stronger and the water from the surface will be kept here to avoid flooding in heavy rain.

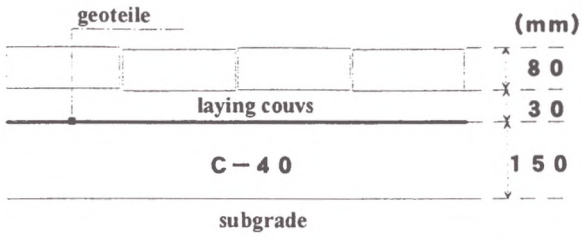

Figure 8.The structure of the sidewalks

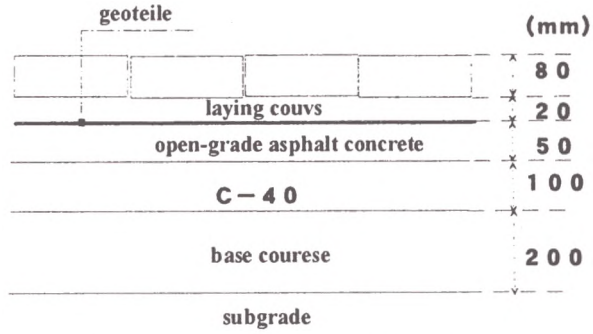

Figure 9.The structure of the roadway

5.FOLLOW-UP SURVEY

The follow-up survey was undertaken immediately after the construction (October 1998), 6 months after (March 1999) and 1 year after (October 1999). The following fears arose about the blocks under cold, snowy weather conditions:

1)deterioration of the block strength through freeze and melt
2)abrasion by tire chains
3)deterioration of the permeability by dust
4)damage to the block corners by the snow clearing work
5)movement of the blocks
6)deterioration of the skid resistance factor

In order to check these points, we undertook the survey in terms of the columns, as shown in Table 7.

Table 7. The survey interms of the columnns

ITEM	THE TESTING WAY
The grade of the deformation	By cross section profile measure
Surface evenness	By length pofile measure
Joint width	By digital calipers
Dynamic frictional coefficient	ASTM E1991-98
Flexure	By HFWD
The permeability	By test of the permeability on theactual spot
The percentage of the damaged blocks	Observing with eyes

5.1 THE GRADE OF THE DEFORMATION

We measured the changes in the height of the blocks in the wheel path at its cross section of the blocks by the cross section profile measure and show the result in Figure 10. After the construction, the profiles are sometime convex, but usually fine semicylinderical. The height of the blocks in the driving lane sank 0.8 mm in 6 months, but stayed the same after 12 months.

5.2 SURFACE EVENNESS

Figure 11 shows the result of the measurement of the surface evenness. The evenness is about 3 mm and has the tendency to increase with time.

But this tendency is very small. The increase of the evenness is bigger in the non-wheel path

than in the wheel path.

5.3 JOINT WIDTH

Figure 12 shows the measurement results of the cross joint width and Figure 13 the length joint width. We evaluated the joint width with the average values n=15 to 31 pieces at five parts (31 cross profiles and 15 length profiles in each part) and the variation coefficient as following;

(1) The joint width changed in the first six months after the construction, but after that didn't change very much.
(2) The cross joint width didn't change in the average, but the variation coefficient became bigger in the 6th month and 12th month.
(3) The length joint width in the driving lane became 0.6 mm wider and that in the non-wheel path became 0.6mm narrower after 6 months. After that there was no change.
(4) The variation coefficient in the wheel path was slightly bigger and that in the non-wheel path smaller.

5.4 DYNAMIC FRICTIONAL COEFFICIENT

Figure 14 shows the results of the measurement of the dynamic frictional coefficient. The dynamic frictional coefficient of the pavement, including the joints, is about 0.5 at 60 km/h and very good. The coefficient hadn't changed very much in 6 months after the construction, but deteriorated a little after 12 months. It is supposed that the reasons for this are supposed that the surface was polished by the driving vehicles and so the aggregate became round. The blocks lost also their edges at the joints.

5.5 THE MEASUREMENT OF FLEXURE BY HFWD

Figure 15 shows the results of the measurement of flexure by HFWD. The flexure of both the wheel path and the non-wheel path had been getting smaller with time. The reasons are that the sand in the joint and the cushion sand had settled down as a result of the traffic.

5.6 TEST OF THE PERMEABILITY ON THE ACTUAL SPOT

Figure 16 shows the results of the test of permeability on the actual spots. The permeability of the wheel path didn't change in 6 months and 1 year after it was completed. But in comparison with the results immediately after the construction, the value is 1.3 to 1.4 times bigger. The joint sand disappeared through the movement of the blocks and rainwater with time and so the contact between the test machine and the pavement became imperfect. The test water was lost through the openings. We suppose that this bad contact of the machine to the pavement is the reason for the change in the permeability.

The permeability of the sidewalks had been reducing with time. Since the blocks in the sidewalks were bigger, the permeability test of one block without the joint parts was possible.

The reason for the reduction of the permeability in the sidewalks is that the holes of the blocks are filled up with earth and dust. Vehicle traffic, it is to suppose, causes the big differences in permeability between the driving lane and the sidewalks.

5.7 DAMAGE

Figure 17 shows the percentage of the damaged blocks according to the years after the construction. The rate of the damaged blocks had increased from the completion of the work to the 6th month, but after that it changed very little. The damage was, under closer observation, just the breaking-off of the corners. So we didn't have to change the whole block. There were hardly any blocks which were damaged by the deterioration of the strength or by the snow clearing work.

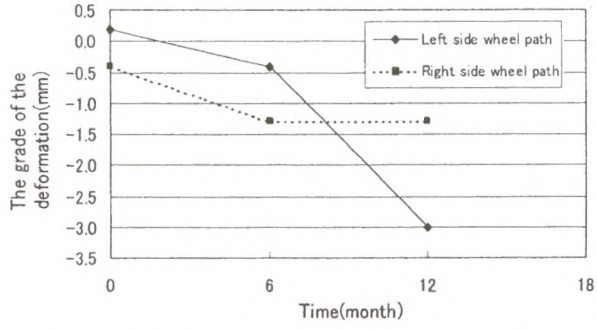

Figure 10. The results of the measurement of the grade of the deformation

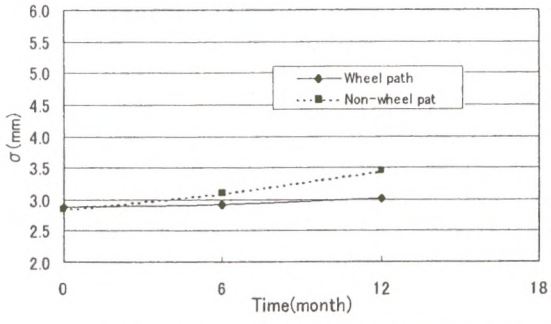

Figure 11.The results of the measurement of the surface evenness

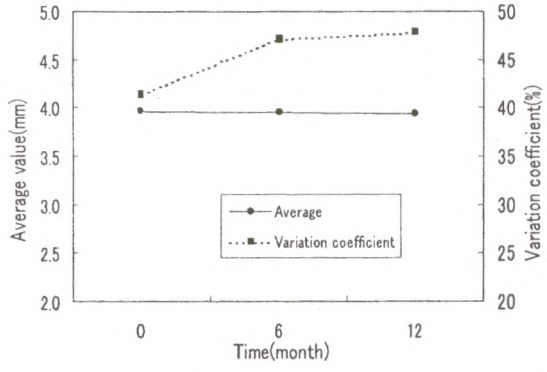

Figure 12.The measurement of the cross joint width

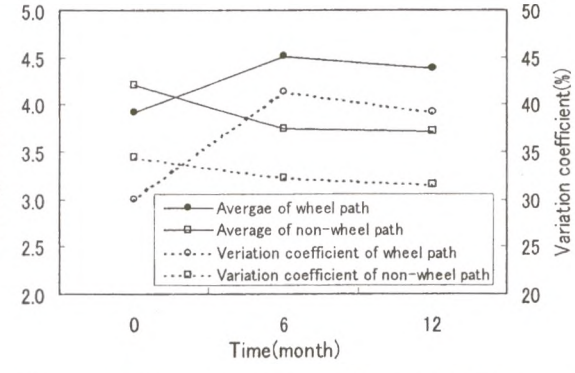

Figure 13.The measurement of the length joint width

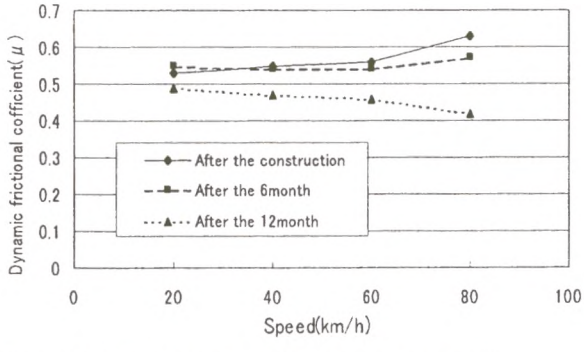

Figure 14. The results of the measurement of the dynamic fictional coefficient

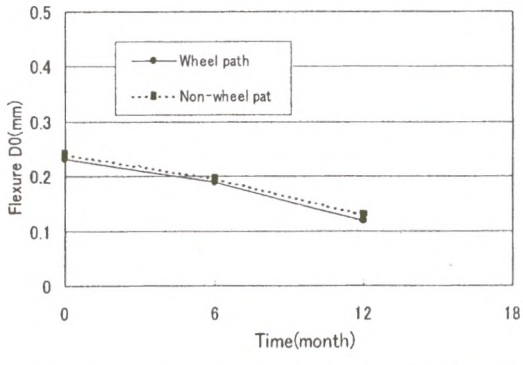

Figure 15. The results of the measurement of flexure

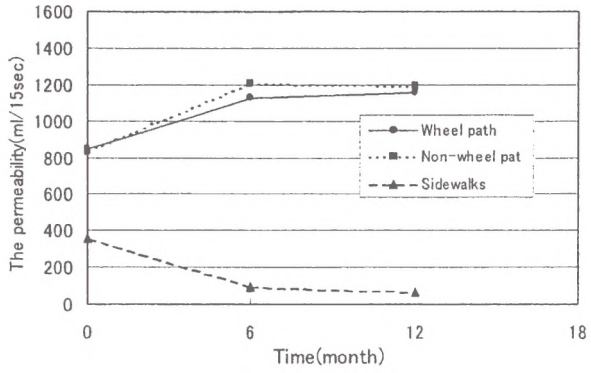

Figure 16. The results of the measurement of the permeability test

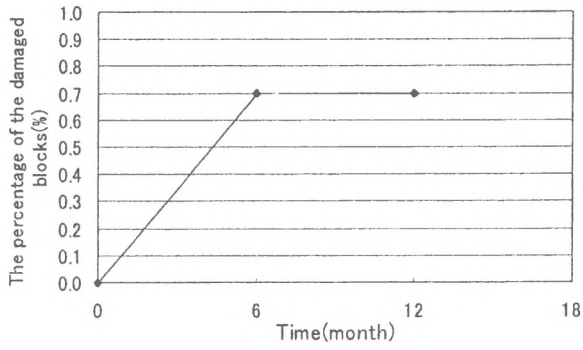

Figure 17. The results of the percentage of the damaged block

6.CONCLUSION

The follow-up survey one year after construction confirms the following:

(1) There were no damaged blocks. The unevenness, flexure and skid resistance were all in good order.

(2) The joint width had slightly changed lengthwise and crosswise because of the load of the traffic. Especially the movement of the blocks lengthwise in the wheel path influenced the blocks in the non-wheel path. But there were no differences in or meandering of the joint lines.

(3) The permeability of the sidewalks reduced because of earth and dust, but that of the wheel path remained good.

The pavement made of permeable interlocking blocks stayed in a good condition one year after the construction even in a cold, snowy area such as like Niigata City. Under certain condition of the subgrade and traffic, covering pavement with permeable interlocking blocks is a successful method for the harmonization with the environment, the control of the draining of the surface and the improvement of the walking conditions.

We will further undertake the follow-up survey and discuss the cleaning methods of the materials which fill up the holes in the blocks and cause one of the reasons for the deterioration of permeability.

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