THE APPLICATION OF THE INTERLOCKING BLOCK PAVING TO A SCRAMBLE INTERSECTION

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SUMMARY

The Interlocking Block Paving (hereinafter abbreviated as IBP) in Japan is mainly applied to light traffic site such as predestrian roads, parks, public squares and roads for both pedestrians and automobiles, but seldom applied to heavy traffic roads. Environmental factors to make the community more comfortable are taken into consideration for all the IBP cases. This research is to do with a 3-year traffic survey on IBP done in November, 1984 at a scramble intersection (60,000 cars per day) of an ancient city, Kanazawa, which tourists visit endlessly throughout the year. Kanazawa City is very famous for its heavy snow-falls which attribute to the damage on lane marks by spiked tires, and it is also very dangerous for tourists who are not geographically familiar to the city. There are traffic accidents often caused by these factors. This research reports the results of a concept survey collected from pedestrians (200 persons) and drivers (185 persons) and the people living in the area (202 persons) who utilize this scramble intersection and also reports the results on the survey on the IBP. The IBP in Japan is contributing to the creation of a more comfortable community and to better traffic safety.

1. INTRODUCTION

An ancient city, Kanazawa, known nationally and internationally as a tourist spot with its antique town-look shows different seasonal faces, and attracts tourists all the time throughout the year.

The city, at the same time, is very famous for its heavy snow-falls in the winter because of which lane marks are easily destroyed by spiked tires and the traffic has to flow on roads without lane marks during the winter time. Therefore, drivers unfamiliar to the city and tourists get often involved in traffic accidents.

Recent popularity of spiked tires attributes to damages on the asphalt pavement and dust pollution and getting image of shopping areas down. We, therefore, paved an urban intersection with interlocking blocks trying to create a "more charming scramble intersection" within a context of the total urban development.

This IBP was done in November, 1984 and during the following Z years a tracing survey on the IBP and a concept survey of users and the people living in the areas were carried out. This reports summarizes the surveys.

2. TEST PAVING AND OUTLINE OF THE SURVEY

2-1. Outline of the Paving Site.

The location of this IBP is Kata-machi scramble intersection (1500 sq.m) on Route 157, and traffic passing through the intersection is 60,000 cars per day, which is one of the urban scramble intersections having the heaviest traffic volume.

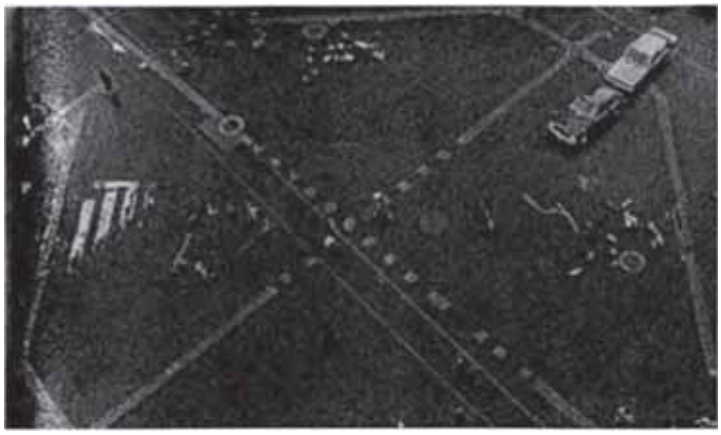


Photo 1:Intersection before IBP



Photo 2:Intersection with white lane marks worn-off (Before IBP, i.e asphalt pavement)

Photos No. 1, 2 and 3 show how lane marks wore off after paving and during winters as compared to the beginning of the pavement.

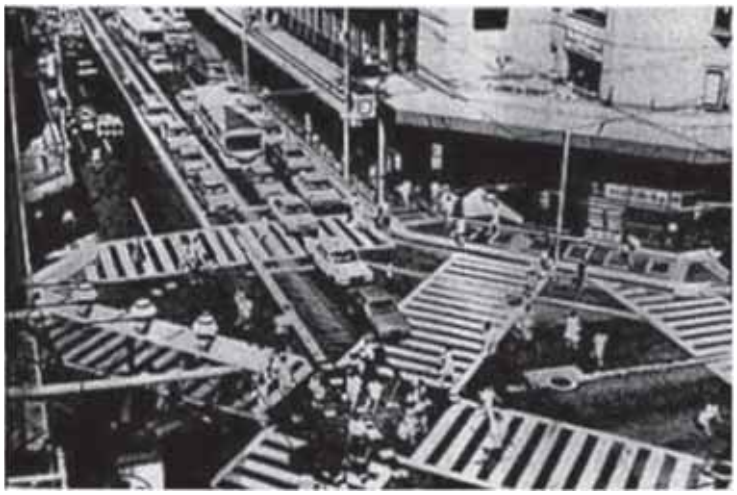


Photo 3 IBP Intersection after 3 winters passed.

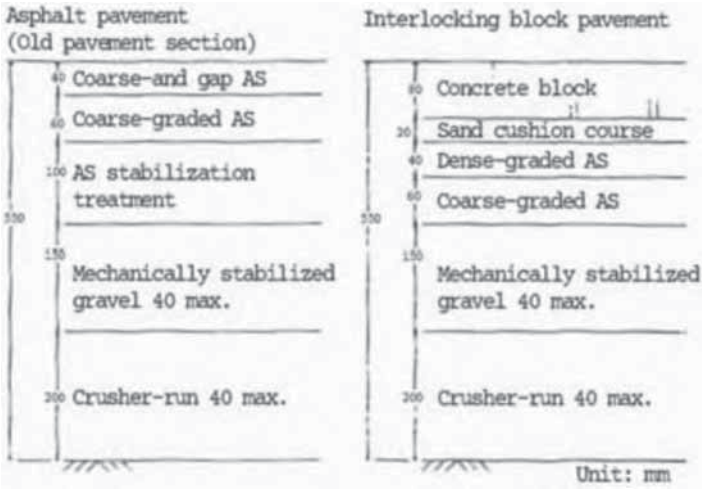


Fig.-1 Pavement structure.

2-2. Pavement Structures.

One of the characteristics of IBP is that each adjoining block interlocks with each other and it copes with deformation with its joints working as hinge.

IBP is rigid pavement as far as materials are concerned but its deformation performance is similar to flexible pacement having intentional chinks, therefore, the designing method of IBP in Japan applies provisionally that of CBR adopted for asphalt pacement taking into consideration various past experiments and research reports of different countries. The pavement thickness is derived from the following equations:

$$H = \frac{28.0N^{0.1}}{CBR\ 0\text{-}6} \quad \text{..... [1]}$$

$$TA = \frac{3.84N^{0.16}}{CBR\ 0\text{-}3} \quad \text{..... [2]}$$

Where:

H = The pavement thickness (cm)

TA = The design thickness, (i.e. the required thickness of a full depth hot mix asphalt pavement having an equivalent strength).

N = The number of equivalent 5-ton wheel-loads in one direction to be expected during the 10-year period following construction.

Accordingly the old asphalt pavement was removed and the flexible pavement composition was condisdered for this pavement which has a cross section as shown in Fig.I.

2-3. Outline of Survey.

The survey is classified into two categories, that is,

(1) In the serviceability test, deformtion of the pavement surface was to be traced and results were to be comprehended paving attention to mechanical characteristics of IBP. IBP.

(2) When the scramble intersection became familiar to the people after 10 months from paving, we were to obtain assessment from pedestrians, people living in the area and drivers using theintersection making a concept survey on the IBP.

These survey items and frequency are shown in Table-1 and the survey method is shown in Table-2.

3. RESULTS OF SURVEY

3-1. Assessment of serviceability.

(1) Results of deflection measurement with Benkalman Beam.

A change of deflection of IBP with the passage of time is shown in Fig-2. A comparison between the IBP and the ordinary asphalt pavements shows that both pavement are stable in serviceability and that the deflection of IBP is a little bit less than that of the asphalt pavement. This may be because the pavement thickness (H=55 cm, TA-28.25 cm) in the pacement structure as shown in Fig.-l is equal and because an asphalt mix(H=10 cm) was used partly on the upper subbase course. Reported data say that characteristics of deflection of IBP in general in the aggregates subbase or the cement stabilized subbase are that it tends to get stable after it keeps decreasing for 6-12 months service time when consolidation under the sand cushion course almost completes. This survey shows stable deflection after service began. This stableness is considered to be attributable to an asphalt mix layer on the subbase.

(2) Results of Plate Bearing Test

The plate bearing test on the surface course is a test for evaluating the

Table 1. Frequency of survey.

Survey items \ Frequency	Service start	3 months (1 winter)	6 months	15 months (2 winters)	27 months (3 winters)
Deflection test with Benkelman Beam	●	●	●	●	●
Plate bearing test	●	●	●	●	●
Cross section profile	●	●	●	●	●
Longitudinal profile	●	●	●	●	●
Abraded quantity survey	●	●		●	●
Skid resistance test	●	●	●		●
Temperature of pavement surface			●		
Appearance inspection	●	●	●	●	●
Questionnaire survey				●	
Traffic volume survey (Implemented by Hokuriku Regional Construction Bureau)		●			

Table 2. Survey items and methods of measurement.

● Adjusted

Items	Method of Measurement
Deflection test with Benkelman Beam	Manual for Low Cost Pavement Appendix-4
Plate bearing test	JIS-A-1215
Cross section profile	By leveling cord and slide calipers
Longitudinal profile	Manual for Design and Construction of Asphalt Pavement Appendix 4-11
Abraded quantity survey	By slide calipers after pulling out blocks
Skid resistance test	ASTM-E-303-69
Temperature of pavement surface	By surface thermometer
Appearance inspection	Datage. cracks etc by eyes
Questionnaire survey	By asking questions

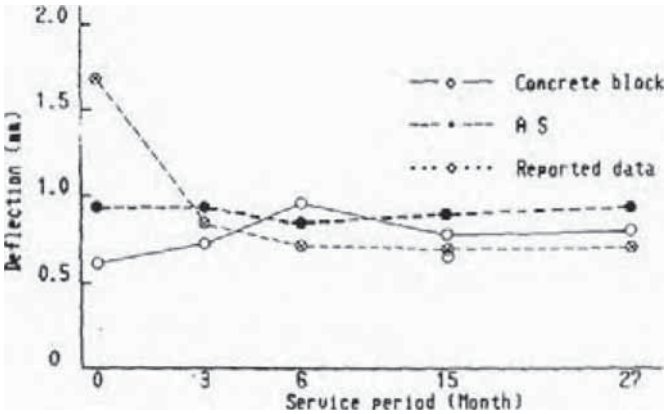


Fig.-2 A change of deflection with the passage of time.

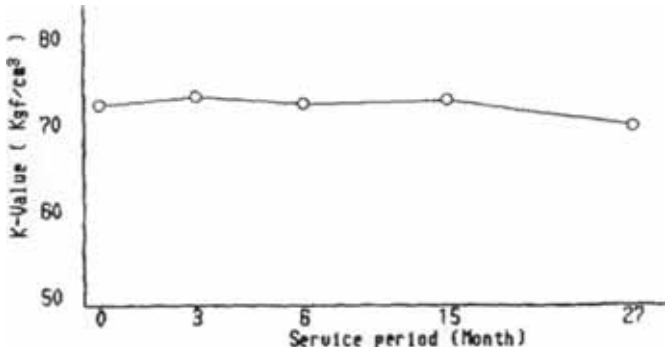


Fig.-3 A change of K-value with the passage of time.

bearing capacity of the total pavement. The K-value of this pavement became stable at the beginning of service and in the end of service like the case of deflection. (Fig-3)
This is well understood since an asphalt mix was layed on the subbase.

(3) Results of Cross Section Profile Test.

Fig.-4 shows an example of changes of the cross section profile based on the measurement results at the beginning of service. The unevenness in this survey comes from a width of the lanes as the survey was . done in a scramble intersection and it generally tends to sink. On the other hand, rutting by the wheels (wear-off by spiked tires rutting by the wheels) was observed on the adjoining asphalt pavement as the location was this side of the

intersection. The unevenness in the scramble intersection seems to be caused here by the wear-off by spiked tires than rutting by the wheels judging from the traffic flow situation.

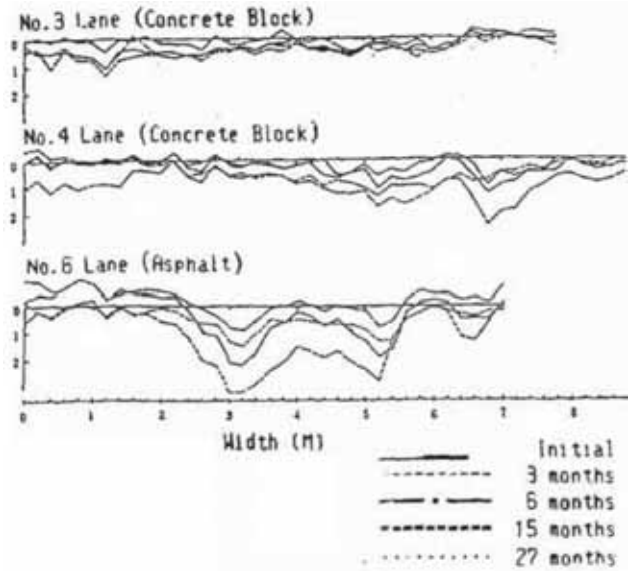


Fig.-4 Cross section profile curve

(4) Results of Longitudinal Profile Test.

Fig.-5 shows changes of the unevenness of the road surface as service proceeds, during 7 months after service began, the enevenness showed a slight increasing trend (worsening of unevenness) from < = 3.9 to < = 4.8. This may be because white blocks and red blocks were layed in a striped pattern and the difference on the wear-off by spiked tires for white and red blocks directly affected the unevenness.

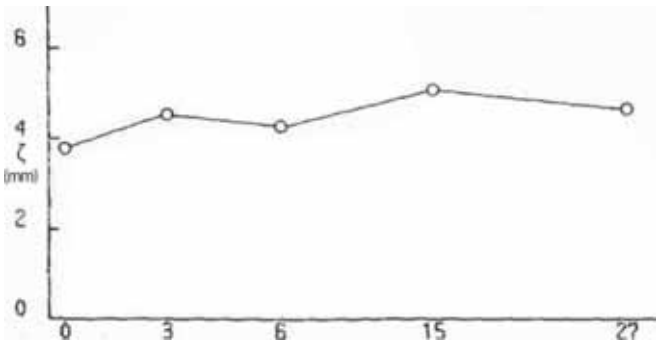


Fig.-5 A change of unevenness with the passage of time.

(5) Results of Abraded Quantity Survey

The abraded quantity of the blocks used on the road surface is shown in Fig.-6. white blocks wore off by 1.52 cm and red ones by 0.43 cm in average after 3 winters (27 months in service, number of days wearing spiked tires is 120 days per a winter) passed.

The former wore off 3 times more than the latter because . white blocks were produced in double layers (mortar layer by concrete layer) while red ones in mono-layer considering abrasion resistance and also because of difference in the raw materials.

Abraded quantity per one million spiked tires cars is assumed to be 1.73 mm for white blocks and 0.49 mm for red ones. From the above results white blocks need to be examined more closely on the abrasion but red blocks produced in mono-layer seem to show good results.

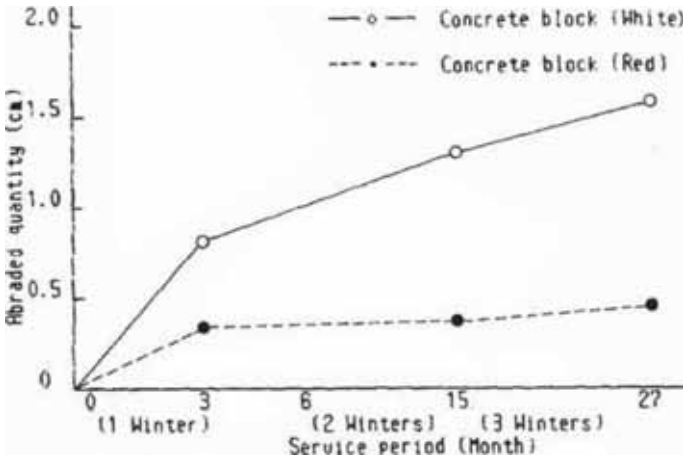


Fig.-6 Results of abraded quantity survey.

(6) Results of Skid Resistance Test.

Changes of skid resistance value with the passage of time are shown in Fig.-7.

BPN value under the wet situation for 27 months from the beginning of service falls within a range of 61-65 (BPN). The values satisfy the basic values for general roads and will supposedly be no problem.

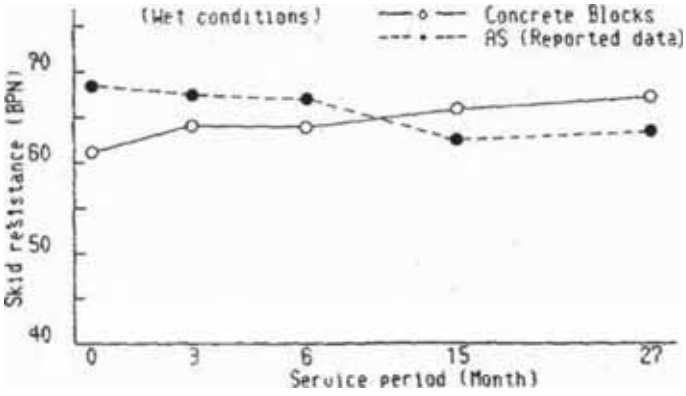


Fig.-7 A change of skid resistance with the passage of time.

(7) Results of Appearance Inspection (Breakage of Blocks)

We found 10 blocks broken out of 640 in the inspection during 3 months in service (1.6%) and only another 4 blocks were found broken during 27 months in service. (Fig.-8) The breakage is only a minor cracking and a cracking in the edge and it does not give any trouble to the traffic or to drivers.

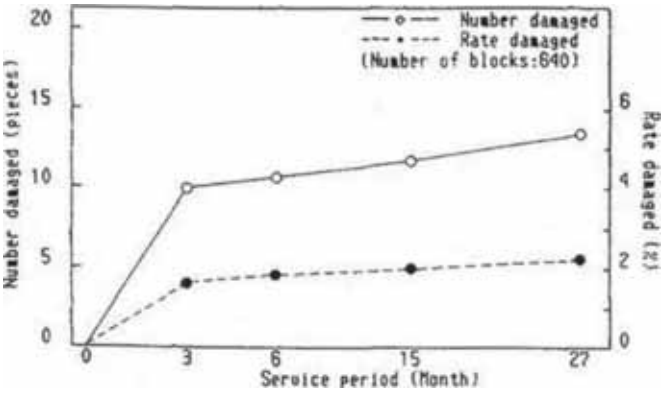


Fig.-8 Damage situation of blocks.

3. ASSESSMENT OF CONCEPT SURVEY OF USERS

After 10 months in service, the intersection became very popular among the people and therefore, we asked the pedestrians, drivers and the people living in the area who utilize the intersection to fill in a questionnaire.

3-1. Survey Method and Contents of Questionnaire.

Questions were posed to 200 pedestrians, 185 drivers and 202 residents in the area (total 587 persons) as shown in Table -3. The questioned consisted of men and women (2:3 ratio) of 15-50 of age.

There are more women than men because women are more sensitive to colors and IBP is colorfull pavement. The outline of the people answered the questionnaire is shown in Table-4.

Table-3 People replied to the question naire. Date of Survey: August 13 1985 (Tuesday)

Object people		Pedestrians	Drivers	People in the area k shopping st
Sex	Male	74	175	77
	Female	126	10	125
Male age	below 20	22	0	11
	21-30	16	17	13
	30-50	12	123	42
	Over 50	24	20	12
Female age	below 20	47	2	25
	21-30	13	3	41
	30-50	36	4	45
	over 50	24	1	14

3-2. Results of the Concept Survey.

(1) Pedestrians

Questions to the pedestrians utilizing the scramble intersection are shown in Table-4. We asked their opinions of such items as impressions of IBP, comparisons to other pavement, variations of joints and colors, suitability as pavement, favourableness of IBP. The results are shown in

Table-4 Outline of questionnaire.

	Contents of Questionnaire
Pedestrians	1) Impressions on the intersection with IBP 2) Easiness for Walking 3) Joints m IBP 4) Assessment on IBP as pavement for and intersection 5) Colors for a scramble intersection 6) Traffic safety in regard to a Near-off of lane marks by spiked tires, etc.
Drivers	1) Comparisons of the conventional asphalt pavement 2) Identification of the intersection 3) Speed on the IBP 4) Necessity of the colors for a scramble intersection
People in the area	1) Suitability of IBP in Kanazama 2) Customer-collecting effect by better impressions 3) Reasons for IBP adoption 4) Necessity of IBP for future community development

Table-5 Pedestrians.

Sex	Male	Female	Total
Questionnaire	175	10	185
Impressions			
Good	0.714	0.800	0.719
Unchanged	0.211	0.100	0.205
Bad	0.029	0	0.027
Comparison			
Bad	0.280	0.100	0.276
Good	0.337	0.300	0.335
Unchanged	0.377	0.600	0.389
View			
Good	0.709	0.900	0.719
Bad	0.103	0	0.097
Noise			
Noisy	0.269	0.100	0.259
Quiet	0.623	0.900	0.636
Speed			
Down	0.314	0.700	0.335
Unchanged	0.689	0.300	0 645
Colors needed	0.688	0.500	0.676
Pavement			
Suitable	0.731	0.900	0.741
Unsuitable	0.080	0	0.076
Liking			
Like	0.571	1.000	0.595
Dislike	0.103	0	0.097

Table-5. Both men and women replied "good" "suitable" and "easy to walk on".

(2) Drivers,

Easiness for identification, noise while driving, speed and suitability of pavement are in particular asked to the drivers, and the results are shown in Table-6. According to the results, 72% replied the IBP to be "good" "unchanged" in driving conditions as compared to the other normal pavement in spite of its having joints and worse surface unevenness, which proved that joints do not influence driving pleasantness to much.

They also said that IBP was easy to identify. If IBP is so designed to have a hump effect, drivers will oblige to drop speed, but it revealed that IBP has an imaginary hump effect as there are 1 driver out of 3 who dropped his speed. It contributes to the safety of pedestrians.

Table-6 Drivers.

Sex	Male	Female	Total
Questionnaire	74	120	200
Impressions			
Good	0.770	0.770	0.770
Unchanged	0.176	0.111	0.135
Bad	0.027	0.008	0.015
Walking			
Good	0.662	0.542	0.575
Unchanged	0.230	0.284	0.270
Not good	0.068	0.135	0.110
Joints			
Anxious	0.162	0.167	0.165
Not anxious	0.770	0.722	0.740
Interesting	0.068	0.087	0.080
Pavement			
Suitable	0.851	0.762	0.785
Unsuitable	0.041	0.024	0.030
Colors needed	0.905	0.617	0.815
Troubled w/discoloration	0.676	0.576	0.815
Reasons			
Impression	0.108	0.127	0.120
Customer Collection	0.068	0.016	0.035
Traffic safety	0.188	0.111	0.140
Liking			
Like	0.757	0.575	0.705
Dislike	0.041	0.040	0.040

(3) People Living in the Area, and Working in Shopping Street.

People utilizing the intersection in their daily life were asked mainly for opinions of whether "IBP is suitable and necessary" for creating a pleasant community in an ancient city, Kanazawa. The results are shown in Table-7. IBP is very popular in Europe and more than 80% of the residents in Kanazawa, too, favour IBP as a material for a more charming community.

Table-7 People in the area and shopping street.

Sex	**Male**	**Female**	**Total**
Questionnaire	77	125	202
Impressions			
Good	0.766	0.712	0.733
Unchanged	0.156	0.176	0.166
Bad	0.039	0.006	0.020
Colors needed	0.696	0.792	0.832
Kanazawa			
Good	0.817	0.752	0.777
Unchanged	0.065	0.080	0.074
Not good	0.026	0.040	0.035
Customer Collection			
Increased	0.117	0.104	0.109
Decreased	0	0.008	0.005
Unchanged	0.636	0.704	0.676
Reasons			
Impressions	0.266	0.360	0.332
Customer Collection	0	0.024	0.015
Traffic	0 . 312	0.166	0.223
Pavement			
Safety	0.883	0.776	0.817
Suitable	0	0	0
Unsuitable	0.039	0.046	0.045
Future			
Needed	0.779	0.660	0.718
Not needed	0.169	0.200	0.188
Liking			
Like	0.753	0.760	0.757
Dislike	0.052	0.056	0.054

4. SUMMARY OF SURVEY RESULTS

We have so far stated results of the various tests done on the IBP for 3 years in service and the following is the summing-up of important points:

(1) In the deflection test, IBP shows less deflection value than the neighboring asphalt pavement with the same cross sectional structure. This is presumed to be a contribution of a load distribution effect by interlocking function of the blocks used on the surface course due to the equal value of H and TA.

(2) The results of the plate bearing test showed almost the same value for 3 years from the beginning of service. This is presumed to be because an asphalt mix was partly layed on the upper subbase.

(3) Although the unevenness of the pavement surface in the longitudianl and cross sections got worse during 3 years service due to abrasion by spiked tires, it does not seem to give any practical problems in driving or walking.

(4) Difference in the abraded quantity between white and red blocks was 3 folds which may be attributed to the different raw materials and production methods. To develop white blocks suitable for the cold and snowy areas is a topic for the future. The abraded quantity in this survey is presumed to be 1.73 mm for white blocks and 0.49 mm for red ones per one million cars passing.

(5) There is no problem in the skid resistance for the traffic and walking.

(6) The appearance test showed no serious damage.

(7) The concept survey showed that the assessment of IBP for the scramble intersection asked to pedestrians, people in the area and drivers was mostly "good" and they seem to have a better feeling towards IBP than the ordinary asphalt pavement.

In this ancient city Kanazawa, there are also a lot of opinions expressing favourableness to IBP which is widely used in Europe as a charming and suitable pavement material in order to create a pleasant community and to meet traffic safety.

5. POSTSCRIPT

These are the results of the tracing survey implemented for 3 years. The intersection turned to be a charming scramble intersection assessed highly by not only people living in the area but also by people utilizing the intersection. No damage by passing traffic loads was observed as worried

about at first, but tbe abraded quantity of white blocks used for a purpose of road marking was as bad as had been expected. IBP in Japan has come to be widely used as it offers such properties as are not given by the conventional pavement, for instance, beautiful joints and wide and free selection of colors. The actual area paved with interlocking blocks in Japan in 1987 has amounted about 3.5 million sq.m. with main applications to pedestrian roads, parks and shopping streets. One of the biggest problems of IBP in Japan is its designing method, assessment method of the pavement. We have been making efforts that IBP shall more be used for heavy traffic roads solving questions of the block itself, especially abrasion problem of white blocks. It is well conceivable that the requirements on the pavement by the Japanese people will diversify and such factors as colors, designs, beautiful appearances and space for creating pleasant human relations will surely become more and more important. Under these circumstances, it is my great pleasure if this report contributes in one way or the other to the prosperous development of IBP.

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