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Development of New Type of Interlocking Block for Roadways

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1. Introduction

The total paved area of interlocking block (hereinafter referred as IL block) in Japan is 150,000,000 ㎡ since IL block was introduced to Japan. But its application to roadways is only 10% and the application rate for roadways has been decreasing year by year. The total IL block pavement area in 2010 was 3,060,000 ㎡ 7% of which was for roadways. This falls on 1/10 of Germany's 65%.The roadway application in Japan is for community roads under N4 (Traffic volume less than 250 More than 100 heavy vehicles per day) grade and a little application for big roads above N5 (Traffic volume less than 1000 More than 250 heavy vehicles per day) grade or large areas. Reasons that IL block does not expand to roadways are that block's efficiencies are not correctly recognized in the market and that it tends to be refrained as different specifications like shape dimensions and spacer rib locations according to manufacturers make maintenance quite difficult. Some of the other reasons are that the initial cost compared to asphalt paving is higher and that many designers prefer rectangular types from the pattern, taste and landscape points of view whereas the current standards recommend corrugated types for roadways. In order to make the market recognize that IL block fits for the recycling type of society breaking the wrong idea and taking lifecycle costs and environment into consideration, Japan Interlocking Pavement Engineering Association (hereinafter referred as JIPEA) developed new type of rectangular inter locking block which fits for roadways with universal design and confirmed many efficiencies through indoor tests. JIPEA afterwards planned actual production and construction onto real roads to appeal to government sectors. As a result, Kotake-town in Fukuoka-ken agreed to the idea and three kinds of IL block, that is, the new type of IL block, corrugated IL block and rectangular IL block were laid on the half-lane of a town road 90 ㎡ (including 60 ㎡ for comparison). Different efficiencies like roughness were surveyed and discussed through tracing tests. This paper deals with the process of developing the new type of IL block for roadways, construction onto a real road and the details of the

test.

2. Development of a new type of IL block for roadways

2.1 Issues for the development

Corrugated IL block is commonly used in Japan now for roadways but rectangular IL block tends to be chosen from the pattern taste of pavement designers and landscape point of view and that doesn't correspond to the market need. If the thickness of rectangular block is changed from 8cm to 10cm, it may correspond to the market need but there may be some manufacturers who cannot afford producing and selling the block because it costs a lot for investment. Also mechanical laying in Japan is not very popular and the new type of IL block for roadways which is heavier gives extra loads to workers and those points were the issues for developing the new type of IL block for roadways.

2.2 Designing Idea of New Type of IL Block for Roadways

(1) Every manufacturer can produce the block on the existing machine without further investment.
(2) The mass should be the same as rectangular IL block which is currently most popular and needed in the market.
(3) The color should be unified and pigmentation is not done for coloring.
(4) The width of spacer rib should be wide improving interlocking and load transfer rate effects and preventing abrasion and wearing.
(5) Since efficiencies and functions should be guaranteed, joint width and height and construction method fit for developing roadways in the public place should be standardized.
(6) Construction methods emphasizing bedding sand and joint sand and maintenance method should be made into manual.

2.3 Verification and selection of New type IL Block laboratory

The result that the IL block order was decided according to the evaluation and rating is shown in the table1 ((1) ~ (7) is the order), the test items and scoring. The rating went like 10 points for the first place, 9 points for the second, 8 points for the third and so on. The evaluation showed that 8cm and 10cm corrugated types showed comparatively high scores and 10cm rectangular type and C-type followed. The C-type was decided as the new and unified type IL block (hereinafter referred as Unified type) because the C-type could keep the same bearing capacity as 10cm rectangular type as spacer ribs

contact area is big.

Table1: Evaluation by the Test Result Ranking

The test items / Blok type	Test small FWD			Test by Loading Plate				Total
	Deflection under the Loading Point	Deflection ratio	Load Transfer Efficiency Index	Settlement	Modulus of Subgrade Reaction	Earth Pressure	Pull- out	
Corrugated type 6cm	6(5)	5(6)	8(3)	8(3)	5(6)	6(5)	8(3)	46
Corrugated type 8cm	10(1)	9(2)	10(1)	10(1)	10(1)	10(1)	9(2)	68
Corrugated type10cm	9(2)	10(1)	9(2)	10(1)	9(2)	10(1)	10(1)	67
Rectangular type 6cm	5(6)	8(3)	9(2)	7(4)	5(6)	5(6)	5(7)	44
Rectangular type 8 cm	6(5)	6(5)	8(3)	8(3)	6(5)	9(2)	7(5)	50
Rectangular type 10cm	8(3)	7(4)	9(2)	10(1)	7(4)	10(1)	6(6)	57
A-type 8cm	7(4)	4(7)	7(4)	10(1)	8(3)	8(3)	-	-
C-type 8cm	8(3)	6(5)	9(2)	9(2)	7(4)	7(4)	7(4)	53

3. Production of Unified type on the Existing Block Machine

The Unified type was produced on the machine of Fukuoka Splitton Industry Co., Ltd. who is a member of JIPEA. The Unified type was shown in the picture1. The produced Unified type was the same as the one made for the indoor test and other properties met the standards.



Figure 1: Unified type produced on the actual Machine

4. Construction on a real Road and tracing Survey

4.1 Plan

The construction place was a town road in Kotake-town on 90 ㎡ half lane and Unified type 30 ㎡, corrugated type (8cm) 30 ㎡ and rectangular type (10cm) 30 ㎡ were constructed. The tracing survey was planned at least for 2years.

4.2 Construction

As each kind of block is surrounded with curb stones for end restraint, we paid attention so that blocks did not move or break by heavy traffic and cross load in construction. We laid first corrugated type then Unified type and rectangular type after surrounding like a picture frame and we used the same quality sea sand for bedding sand and joint sand. The finishing was done using a macadam roller taking into subbase

roughness and the entire construction took 10days.

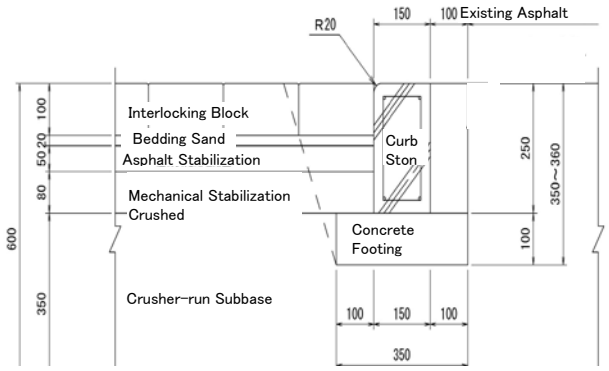

Figure 2: Structure of Curb Stone for End Restraint (mm)



Figure 3: Finished Scene

4.3 Items for Tracing Survey and Measuring Method

The items and the measuring methods are shown in the table2. In addition to each testing item, pulverizing of sand, skid resistance and traffic volume surveys were implemented together. The survey was carried out after 3 months, 6 months and 1 year.

Table2: Survey Items and Measuring Method

Survey Items	Measuring Method
Rutting	Measuring Rutting on the Pavement Surface (Pavement Survey and Test Method Manual S042)
Flatness	Measuring Flatness of the Pavement Surface (Pavement Survey and Test Method Manual S028)
Road Surface Bearing Capacity	Test Method for Bearing Capacity of Subgrade Reaction by Small FWD (Pavement Survey and Test Method Manual S043-2T)
	Test Method for Loading Plate((Pavement Survey and Test Method Manual S042)
Block Breakage	Measuring Method of Interlocking Block Pavement Breakage (JIPEA-TM-9)
Block Movement	Measuring by Leveling Cord
Faulting Between Blocks	Measuring Method of Interlocking Block Pavement Faulting (JIPEA-TM-3)
Joint Width	Measuring Method of Interlocking Block Pavement Joint Width (JIPEA-TM-10)
Other Survey Items	Confirmation of Pulverization of Bedding Sand: Aggregate Sieving Test (JIS A 1102) Confirmation of Skid Resistance: BPN and DF Tester Traffic Volume Survey: 24hours every week day and 24hours Holidays

4.4 Results of Tracing Survey

4.4.1 Survey Result for Rutting

The survey result for rutting is shown in the Figure4. It was within the range of 2.0 mm~2.4mm and 3.1mm~ 4.6mm after 3months.Each Zone increased to 1.5 ~2.0 times from the construction. It seemed to settle down to 3.2 ~4.5 for Unified type and rectangular type after 6 months. Corrugated type showed increasing tendency and rutting reached double compared to other zones but the value was no problem as it is small enough compared to the standard 30mm.

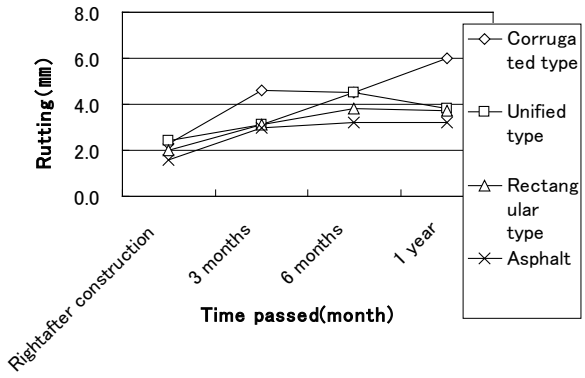

Figure 4: Survey Result for Rutting

Table 3: Survey Result for Flatness, Deflection and Modulus of Subgrade ReactionK30

Compartment	Flatness (mm)				Deflection Ratio (mm)				Modulus of Sub grade ReactionK30(kgf/cm³)			
	Right after	3 months	6 months	1 year	Right after	3 months	6 months	1 year	Right after	3 months	6 months	1 year
Corrugated type	1.85	2.07	2.42	2.41	0.27	0.57	0.51	0.52	71.9	92.2	58.1	83.1
Unified type	2.28	2.42	2.22	2.11	0.35	0.59	0.51	0.57	63.3	121.1	86.5	83.1
Rectangular type	2.20	2.38	2.99	2.48	0.32	0.58	0.54	0.55	65.2	103.4	53.0	53.0
Asphalt	3.46	3.48	3.46	3.07	-	-	-	-	121.1	136.8	90.2	108.7

4.4.2 Survey Result for Roughness

The survey result for roughness is shown in the Table3. 10% increased in every zone after 3 months and more than 10% increased for corrugated type and rectangular type after 6 months but it seemed to settle down after 1year. The Unified type showed the best result after 6 months and 1 year.

4.4.3 Survey Result for Road Surface Bearing Capacity

(1) Test Result by small FWD

The test result converted to deflection ratio is shown in the Table3, setting the deflection ratio of the good part to be over 0.2 and the ratio of the broken part to be under 0.1. The deflection ratio right after the construction in every construction zone fell between 0.27 ~ 0.35 which had no problem. The value thereafter for each zone was equal and it was 0.57 ~0.59 after 3 months, 0.51 ~ 0.54 after 6 months and 0.52 ~ 0.57 after 1 year which was double the figures of right after the construction. The load transfer efficiency index was also the same for all the zones showing 0.42 ~ 0.50 right after the construction, 0.67 ~ 0.71 after 3 months, 0.64 ~ 0.75 after 6 months and 0.68 ~ 0.74 after 1year which was 30% ~ 70% more than that of right after the construction. Deflection ratio and load transfer efficiency index in every zone started to increase after 3 months from the construction and stayed stable for 1year. From these results, it is assumed that interlocking effect in every zone was enhanced and load distribution is well maintained.

(2) Result for Loading Plate Test

The result for loading plate test is shown in the Table3. Modulus of subgrade reaction K30 (K30 = 20 kgf/㎤) was approximately 1/2 of existing asphalt pavement right after the construction. It increased to 1.3 ~ 1.9 times after 3 months compared to right after the construction. It decreased after 6months more than 3 months and after 1year it increased in the order of existing asphalt pavement>Unified type = corrugated type>rectangular type.

4.4.4. Survey Result for Block Breakage

The breakage as time passes is shown in the figure5. A little chipping was seen on Unified type. Breakage right after the construction was 0.7% and it was 1.6% after 1year which was no problem as it was less than the standard of 20%. In the other zone, it was as small as less than 0.1% after 1year survey. All the chippings were very trivial giving no serious damage to the block function.

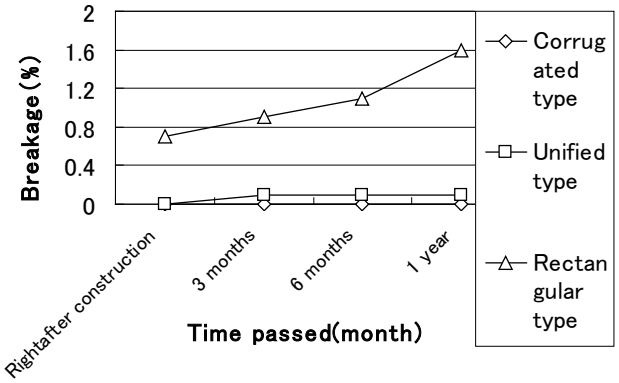

Figure 5: Breakage as Time Passes

Table 4: Survey Result for Movement, Faulting and Joint Width

Compartment	Construction Zone Movement (mm)			Faulting (mm)			Joint Width (mm)			
	3 months	6 months	1 year	3 months	6 months	1 year	Right after	3 months	6 months	1 year
Corrugated type	0.3	2.2	3.7	0.3	0.4	0.4	2.4	3.2	3.0	3.1
Unified type	1.5	1.9	2.4	0.4	0.4	0.5	3.3	4.0	3.8	3.9
Rectangular type	0.5	2.0	0.8	0.5	0.5	0.7	2.3	2.5	2.5	2.6

4.4.5 Survey Result for Movement, Faulting and Joint Width of Block

The respective survey results are shown in the Table4. Movement showed a bit big average 1.5mm after 3 months for Unified type in two zones but it settled to average 1.9 mm after 6 months for all the zones. Corrugated type showed the biggest value of average 3.7mm and Unified type showed the smallest of average 2.4mm after 1 year. Faulting showed average less than 0.5mm after 1 year for both Unified type and corrugated type. Rectangular type showed increasing value of average 0.8mm after 6 months but it was 0.7mm after 1 year almost the same as that of 6 months. Each zone showed lower value of 1/5 ~ 1/10 of the control standards.

Joint width increased by average 0.2mm ~ 0.7mm for each zone. It was equal values to 3 months average after 6 months and 1 year and it was less than control standards of 5 mm. Unified type showed bigger values compared to other zones but it is no problem as the spacer rib thickness was designed at 3mm making no difference to corrugated and rectangular types.

4.4.6 Other Survey Results

(1) Pulverization of Bedding Sand

Bedding sand of all zones were collected and sieved. The fineness modulus of each zone had an equal quality to the beginning. Sieving of joint sand was carried out and it attributed that the fineness modulus of Unified type showed higher fineness modulus. It is assumed that the wider joint width of Unified type compared to other zones may be the cause.

(2) Skid Resistance

A measurement on IL block itself was implemented by BPN right after the construction and 6 months later and a measurement on the real road by DF tester was implemented right after the construction, 6 months and 1 year later. The control standards of BPN of more than 60 for all the zones and the time and the control standards of dynamic coefficient of friction 0.3μ were all cleared without any trouble.

(3) Traffic Volume Survey

The traffic volume survey was implemented for weekdays 24hours and holidays 24 hours and the traffic volume classification for weekdays was N4 (Traffic volume less than 250 More than 100 heavy vehicles per day) and for holidays was N3 (Traffic volume less than 100 More than 40 heavy vehicles per day).

4.5 Summary of Conclusion and Tracing Survey on the actual Road and Future Issues

(1) Construction

It took 10 days for 90 ㎡, a bit longer for construction in this test attempt. It was due to setting up curb stones for end restraint every 10m but if end restraints exist in the construction area in actual construction, there will be no problem and we confirmed that the construction using Unified type can be done with the same labor force as 8cm IL block which is at present popularly used in Japan. That a little settlement was recognized around curb stones as the construction period proceeded may be an issue. It is assumed that the settlement took place as macadam roller could not be used around curb stones instead plate compactor was used, which made difference in compaction. Discussions on products used for end restraints, structure and construction, quality standards of joint sand which harmonize with Unified type are planned in the future for establishing construction manual for Unified type.

(2) Tracing Survey

It was confirmed in the tracing survey that in the various tests, the Unified type could be used for roadways without any trouble exhibiting sufficient functions compared to other types.

Appreciation

We would like to express our gratitude to Taiheiyo Cement Co., Ltd. for developing this product, to Fukuoka Splitton Industry Co., Ltd. for producing Unified type of IL block used in the test construction and to Iwata Co., Ltd. for producing corrugated type of block. We also thank Kotake-town for providing the town road for the test construction.