STUDY OF QUALITY STANDARDS ON CONCRETE PAVING BLOCKS FOR ROADWAY

SHIGEO SUDA, TAIHEIYO CEMENT CORPORATION
2-4-2,Osaku,Sakurashi,Chiba,285-8655 JAPAN
TEL.:+81-43-489-3851,FAX.:+81-43-489-3821
E-mail: shigeo_suda@taiheiyo-cement.co.jp
AKIHIKO KARASAWA, TAIHEIYO CEMENT CORPORATION
TOSHIO HAMAMATSU, JAPAN INTERLOCKING BLOCK
PAVEMENT ENGINEERING ASSOCIATION

ABSTRACT

In present Japan ,less than 10% of all the concrete paving blocks (interlocking blocks) are used for roadways. Japan Interlocking Block Pavement Engineering Association(JIPEA) underwent revision of the Design and Construction Manual and it also underwent reexamination on the quality standards of blocks for roadways in order to promote usage to roadways. The design traffic volume was increased from the conventional volume of 1,000 (vehicles/day one-way) to 2,000 (vehicles/day one-way) in traffic of commercial vehicles. The design period was also extended from 10 years to 20 years. The quality of blocks bearing these conditions was examined and the quality standards were determined. Durability, riding quality and environmental appropriateness which are some of the properties required for roadways and which are managed by the quality of block were studied, too.

1. INTRODUCTION

Interlocking blocks in Japan have been used mainly for walkways, parking lots and roads for light traffic without traffic by commercial vehicles and less than 10% of all the interlocking blocks were used for roadways. But environment to use blocks for roadways has been being born thanks to JIPEA's longtime efforts. Under the circumstances, JIPEA underwent revision of the Design and Construction Manual for Roadways aiming at wide usage in roadways. Major revisions were that the traffic volume of commercial vehicles were revised from 1,000 (vehicles/day one-way) to 2,000 (vehicles/day one-way) and the design period from 10 years to 20 years. Thus the quality standards of interlocking blocks for roadways were also restudied. This paper reports on the study of the quality standards in JIPEA.

2. REQUIREMENTS FOR ROADWAY PAVEMENT

The properties required for roadway pavement are roughly classified into durability, riding quality and environmental appropriateness as described in Table 1. The rough

classification is classified further into items as shown as small classification in the table. These items are all important requirements for roadways. The block qualities deeply related with these requirements are shown in the table. When revising the quality standards of blocks for roadway pavement, these qualities should be sufficiently examined.

Table 1 Relationship between Requirements for roadways and the Quality of Blocks

Requirements		Importance in roadways	Relation to block quality	Related quality items
Rough classification	Small classification			
Durability	Load resistance	◎	Yes	Strength
	Rutting	◎	Yes	Shapes & Dimensions
	Chipping	◎	Yes	Spacer nibs
	Wearing	◎	Yes	Wearing resistance
	Freeze-thaw	◎	Yes	Freeze-thaw resistance
Riding quality	Skidding	◎	Yes	Skid resistance
	Drainage	◎	a little	
	Roughness	◎	a little	
	Difference in level	◎	Yes	Tolerance of dimension Chamfering method
	Visual recognition	◎	Yes	Whiteness
Environmental appropriateness	Low noise	◎	Yes	Chamfering dimensions
	Landscape	○	Yes	Color, texture, shapes
	Permeability	◎	Yes	Coefficient of permeability
	Improvement of environment alongside streets	◎	Yes	
	Recycle	◎	Yes	Materials used

◎ Important

○ Slightly important

Table 2 Requirements Mainly Studied

Requirements	Methods for Management	
	By provisions for quality standards of blocks	By provisions for design and construction
Chipping resistance of block	Provisions for spacer nibs set forth to secure joint width	To set up limits to deflection
Wearing resistance of block	Provisions to guaranty wearing resistance to be set forth	
Skid resistance	Provisions for skid resistance to be set forth	
Difference in level	Provisions for dimensional tolerance and for chamfering dimensions to be set forth	Provisions for roughness
Low noise	Provisions for chamfering dimensions to be set forth	Provisions for roughness
Recycle	To promote recycling by provisions for properties	

3. FEATURES OF THE REVISION

When the present Design and Construction Manual were reexamined from the view point of requirements for roadways, the requirements shown in Table 2 were considered necessary to be improved. These requirements should be managed with the quality standards of blocks in one hand and with the combination of design/ construction provisions on the other. Thus in revising the quality standards of interlocking block this time, these requirements were mainly studied.

4. METHOD OF STUDY

The quality standards of blocks for each requirement were studied according to the methods described in Table 3.

(1) Production Method of Block

On the premise to study the quality standards of blocks, it was studied whether the production method should be with surface mortar or without it.

(2) Chipping Resistance of Block

Positions and numbers of installing spacer nibs in order to secure sufficient joint width was studied based on the results of verifying the mechanism of the occurrence of chipping. Apart from that, an influence of concrete mix proportions(especially aggregate grading) over chipping was studied.

(3) Wearing Resistance of Block

Other properties such as mix proportions and strength were examined for the relation to wearing of block.

(4) Skid Resistance

Concrete mix proportions were examined for the relation to skid resistance.

(5) Difference in Level

It was studied with regard to difference in level that difference in level after construction should be restricted to a minimum by lowering the tolerance of thickness of block as much as possible and that the chamfering dimensions should be minimum within the proper range that wheels running onto the next block should not cause any shocks when chamfering dimensions of the block surface are lowered.

(6) Low Noise

Reducing riding noise was to be managed by checking the chamfering dimensions. Although it is said that using porous concrete is effective for reduction of noise, only normal concrete blocks were objectives for the manual this time and a separate design and construction manual is to be prepared for permeable pavement after sufficient studies on pavement structure and serviceability.

(7) Recycle

It is unavoidable for building a circular society to effectively use various wastes to recycle and interlocking blocks have also been already widely recycled. The study was conducted taking recycling into consideration.

5. MIXING TEST FOR DETERMINING THE QUALITY STANDARDS

Blocks for roadways are to be produced generally without surface mortar as mentioned before. Therefore, unlike blocks with surface mortar, the quality determined by concrete mix proportions will directly influences the properties of the block surface. The aggregate qualities, especially aggregate grading and mix proportions were examined relating to such surface properties as strength, skid resistance, wearing resistance, chipping resistance.

(1) Test Conditions

The mix proportions used in the test are shown in Table 4. The maximum particle grain size was subjected to the variation range from 13-1.2mm and fineness modulus was subjected to 3 variation steps for the maximum size of 13mm and 5mm. Unit content of cement was determined as the unit volume normally used for the respective aggregate size. Unit content of water was determined as a maximum within a range that blocks can be molded without defects like plastic deformation in each mix proportion.

Table 3 Method of Study for the Quality Standards

Requirements	Method of Study
Production method of block	With or without surface mortar
Chipping resistance of block	①Verification of the chipping mechanism to check up (positions and numbers)spacer nibs—separately reported
	②Concrete mix proportions
Wearing resistance of block	Concrete mix proportions
Skid resistance	Concrete mix proportions
Difference in level	①Thickness accuracy
	②Chamfering dimensions
Low noise	Chamfering dimensions No study on porous concrete this time
Recycle	To promote recycling

(2) Test Items and Test Method

The tests described in Table 5 were carried out for blocks molded according to the conditions of Table 4. Rebound number by Schmidt hammer was checked for wearing resistance in addition to a test by studded tires. This methods were to be recommended as simple methods for daily control if co-relation was found between them.

Skid resistance was tested with portable tester(ASTM E 303) and Dynamic Friction tester(DF tester) which is said to co-relate well from high speed to low speed for adopting either one.

Chipping resistance was tested in Cantabro test and torque when chipping takes place

was measured by inserting a torque wrench into block joint.

Table 4 Mix Proportions

Specimen No.	Maximum Size of Aggregate (mm)	Fineness Modulus of Aggregate (FM)	Unit Content of Cement (kg/m^3)	Unit Content of Water (kg/m^3)
1	13	4.50	350	130
2	13	4.09	350	130
3	13	3.69	350	140
4	10	3.81	350	135
5	5	4.29	425	145
6	5	3.71	425	130
7	5	3.13	425	140
8	2.5	2.58	500	140
9	1.2	2.02	500	170

Table 5 Test Items and Methods

Properties	Test Items	Test methods
Strength	Bending strength (7 days curing)	JIPEA test method
	Compressive strength (7 days curing)	JIPEA test method (by ϕ 8 x 8cm core)
Wearing resistance	Wearing	Wearing test by 5in.studded tires (50,000 runs)
	Rebound number	Schmidt hammer N type , wet condition
Skid resistance	Skid resistance	Portable tester(ASTM E 303)
		DF tester
Chipping resistance	Cantabro test	Measurement of weight loss of block by Los Angeles abrasion test
	Chipping torque	Measurement of torque at chipping by torque wrench

(3)Results

1) Wearing Test

The relationship between FM of aggregate and wearing volume is as per Figure 1. The coarser the particle grain size is, the less wearing volume becomes. It means that high wearing resistance is obtained without surface mortar. Figure 2 shows the relationship between bending strength and wearing volume. Wearing volume tends to decrease as strength increases implying that more than a certain level of wearing resistance can be obtained by securing strength.

＊＊Significance level 5%

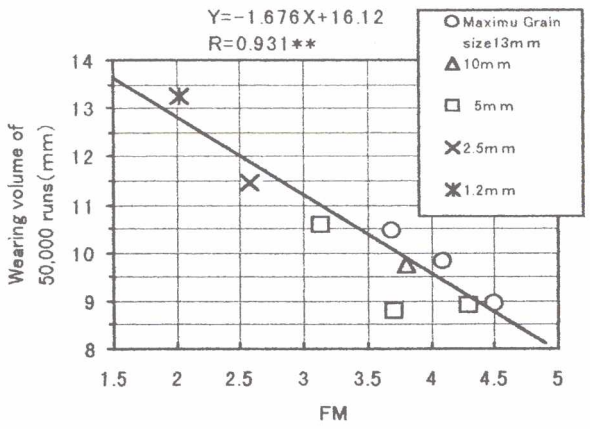

Figure 1 Relationship between FM Bending and Wearing Volume

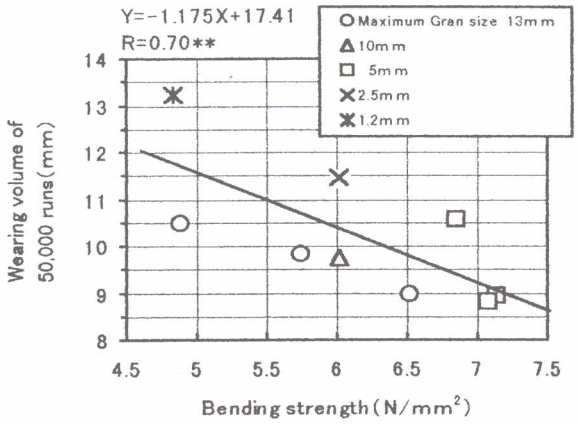

Figure 2 Relationship between strength and Wearing Volume

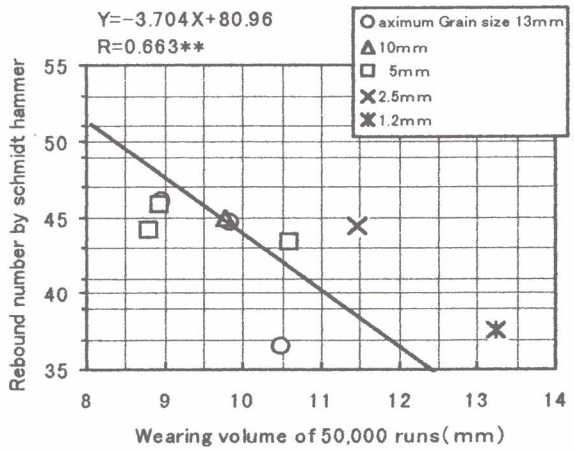

Figure 3 Relationship between Rebound number and wearing Volume

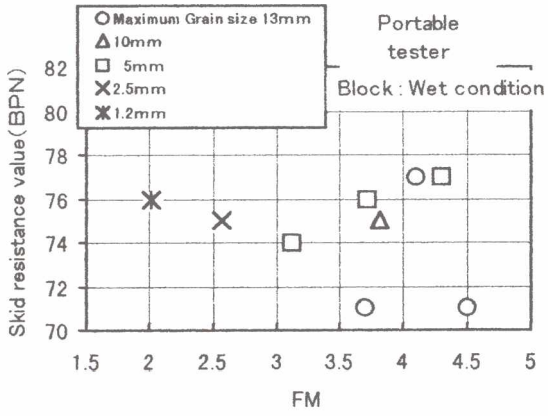

Figure4 Relationship between FM of Aggregate and BPN Value

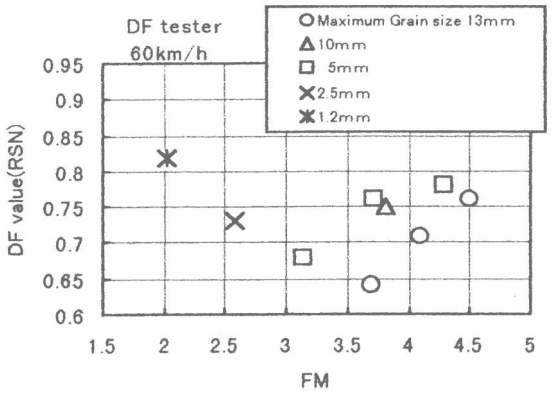

Figure 5 Relationship between FM of Aggregate and DF Value

Figure 7 shows the relationship between the maximum grain size and chipping torque and shows a tendency that torque causing chipping increases as the aggregate size gets larger resulting in less chipping.

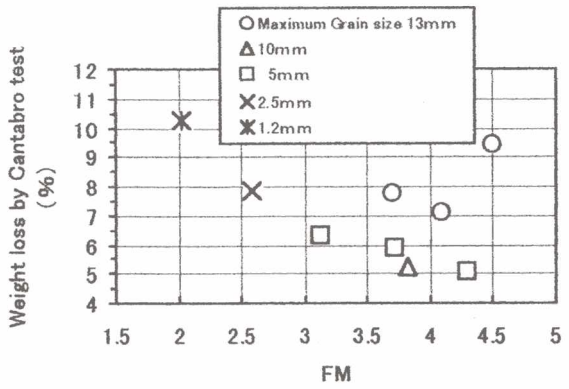

Figure 6 Relationship between FM of Aggregate and Weight Loss by Cantabro Test

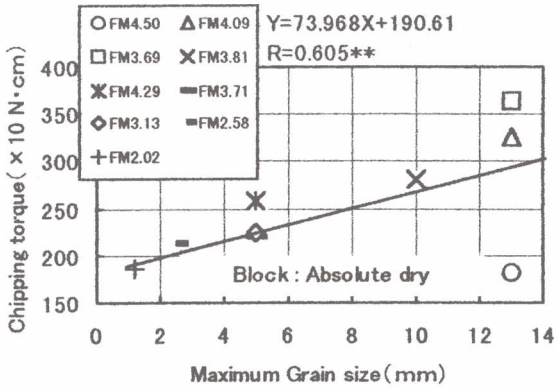

Figure 7 Relationship between Maximum Grain size and Chipping Torque

6. RESULTS OF STUDY

The quality standards of blocks were studied as follows.

(1) Production Method of Block

The surface properties with high wearing resistance and others during the design period of 20 years are required for blocks for roadways. Since the test results of mix proportions described in Section 5 show that blocks using coarse aggregate ended up with much better wearing resistance and chipping resistance, it was determined that blocks for roadways are to be basically produced without surface mortar.

(2) Chipping Resistance of Block

The occurrence of chipping of block depends on deflection and joint width as described in a report(Discussion on Influence on Chipping of Blocks by Deflection and Joint Width of Interlocking Block pavement) and it was demonstrated that chipping can be prevented by making deflection less than 3mm and joint width less than 1mm. The report also suggests positions and numbers to install spacer nibs to secure joint width of more than 1mm. Accordingly, positions and numbers of spacer nibs necessary for each shape of block for roadways were set forth as shown in Figure 8.

It was also recognized from the concrete mix proportion tests that the bigger the aggregate size is the less chipping occurs. That is to say that producing blocks without surface mortar means to reduce chipping.

(3)Wearing Resistance of Block

It was recognized from the mix proportion tests that the bigger the aggregate size is the better wearing resistance and wearing resistance is to be secured by producing without surface mortar. Since wearing volume co-relates greatly to strength, more than enough

wearing resistance can be secured by securing strength.

(4) Skid Resistance

It was recognized from the mix proportion tests that both BPN value and DF value fall in a safe range for skid resistance of block and it was added in the quality standards as it is important from the safety point of view for roadways. The portable tester was adopted for the test method because testing is simple and it is widely used in Japan. The standard value was set at more than 60 BPN.

(5) Difference in Level

It was settled for difference in level that difference in level after construction should be restricted to a minimum by lowering the tolerance of thickness of blocks much as possible and the chamfering dimensions were selected from the dimensions which do not cause any shocks when wheels run on to the next block and which cause less chipping. Accordingly, the thickness tolerance of block was set at $\pm$2.5mm and the chamfering dimensions were set as shown in Figure 9.

(6) Low Noise

Reduction of riding noise was to be managed by setting the chamfering dimensions as shown in Figure 9.

(7) Recycle

Based on efficiency-standard oriented idea and to promote recycling various wastes, it was agreed that wastes which can suffice the quality standards of blocks for roadways can be used.

7. QUALITY STANDARDS OF NEW BLOCKS FOR ROADWAYS

(1) Kinds of Block

The kinds of block should be normal one. The normal block refers to block which is commonly used and not permeable or vegetational block.

(2) Surface finishing

The surface finishing of block should be without surface mortar.

(3) Shapes, Dimensions and Spacer Nibs

Blocks should have spacer nibs.

The shapes, dimensions, of block should, positions of spacer nibs and numbers of installation be as per Figure 8.

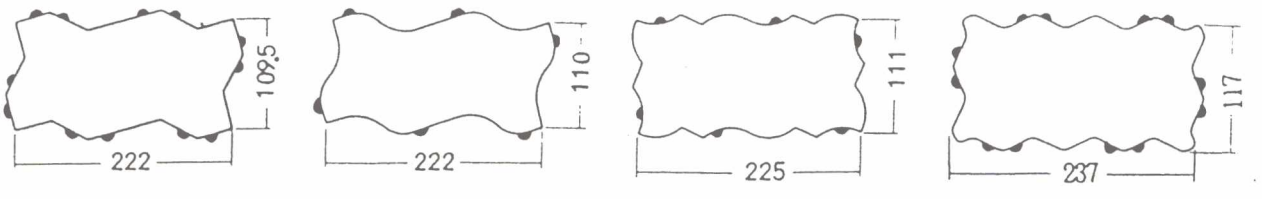

Figure 8 Shapes, Dimensions and Spacer Nibs of Block for Roadways

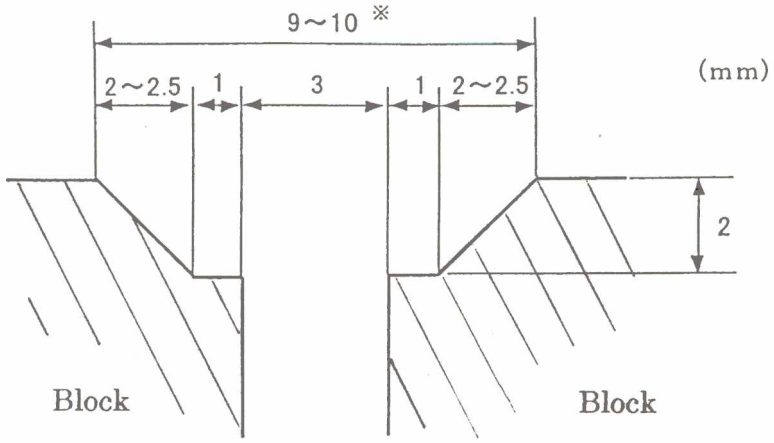

Figure9 Chamfering Dimensions of the Block Surface

(4) Chamfering

The chamfering dimensions are represented in Figure 9.

(5) Thickness of Block

The standard thickness of block should be 80mm.

(6) Quality Standards of Block

1) Appearance

Blocks should not have scratches, cracks, chipping and deformation.

2) Quality

The quality of block should comply with the standards shown in Table 6.

Table 6 Quality Standards of Block

Traffic Category	Item	Standards
Roadway(I -V)	Dimensions (width, length)	Within±2.5mm
	Thickness	Within ±2.5mm
	Strength (bending strength)	More than 5.0N/mm^2
	Skid resistance (BPN value)	More than 60

Note: The traffic category is classified as follows depending on numbers of the commercial vehicles per day.

I: Less than 10 vehicles
II: 10-100 vehicles
III: 100-250 vehicles
IV: 250-1,000 vehicles
V: 1,000-2,000 vehicles

8. CONCLUSIONS

JIPEA underwent revision of the Design and Construction Manual for Roadways in prospect of diffusing blocks for roadways and reexamined the quality standards of block for roadways. The sites where blocks were used are going to be investigated and the compatibility of the Manual and the quality standards are going to be verified henceforth.

REFERENCES

1.DIN 18501 Pflastersteine aus Beton
2.ASTM C 936-96 Standard Specification for Solid Concrete Interlocking Paving Units
3.Max J. Setzer,Volker Hartmann, Improved Frost/De-icing Salt Resistance Testing of Concrete Elements, Betonwerk-Fertigteil-Technik 6,9/1991
4.Klaus Felsch, Precast Concrete Paving Blocks-Good Quality through Good Design, Betonwerk-Fertigteil-Technik 7/1989