DEVELOPMENT OF THE INTERLOCKING BLOCK FOR DRAINABLE PAVEMENTS

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ABSTRACT

Effects of raw materials and mixture proportions of interlocking blocks upon flexural strength and water permeability were examined to obtain a drainable paving block with a high flexural strength and air void of 25 to 30 % necessary for the carriageway application. When a high-early-strength portland cement and admixture of air-entraining and high-range water-reducing admixture and a special absorbent polymer were used, satisfactory performances such as flexural strength of 4.5 N/mm^2 and coefficient of permeability of 0.8 cm/s at air void of 28 % and flexural strength of 5.0 N/mm^2 and coefficient of permeability of 0.3 cm/s at air void of 25 % were obtained in contrast to the drainable asphalt compound with a permeability of about 0.01 cm/s.

1. INTRODUCTION

Drainable paving has been expected to solve the road and roadside environmental problems such as safety driving under wet conditions, traffic noise reduction and heat island phenomena. The drainable paving is now made mainly by asphalt compound whereas the subsequent compaction reducing air void leads to a limit in porosity less than 20 % and to the associated durability problems. Alternative drainable paving system using porous concrete can have a higher air void than that of the asphalt compound and maintain the original high air void resulting in the persistent permeability, whereas considerable reduction in mechanical performances such as flexural strength may result associated with the high air void.

This paper deals with the development of new interlocking block for drainable paving applicable to carriageway, which was accomplished by higher air void of 25 to 30 %, unattainable by the asphalt compound, and by the examination of raw materials and mixture design through the evaluation of flexural strength and permeability.

2. EXPERIMENTS

2.1 Materials used

Materials used in this experiment are listed in Table 1. Chemical admixture were a polycarbonic acid type air-entraining and high-range water-reducing admixture and a special absorbent polymer. Aggregates were crushed stones: No. 6 crushed stone screened to have a 5 to 10 mm in size and No. 7 crushed stone.

Table 1 Materials used

Materials		abbreviation	Density (g/m^3)	Absorption (%)
Cement	high-early-strength portland cement	C	3.13	—
Aggregate	No. 6 crushed stone (5 to 10 mm)	G_1	2.70	1.17
	No. 7 crushed stone.	G_2	2.65	0.94
Admixture	air-entraining and high-range water-reducing admixture	SP	1.05	—
	special absorbent polymer	PQ	0.97	—

2.2 Mix proportions

In order to attain the targeted 25 to 30 % air void of the interlocking block, dosage of air-entraining and high-range water-reducing admixture and absorbent polymer, unit cement content and grading of aggregate were combined into 7 mixture proportions A to G as shown in Table 2, and the resulting performances were evaluated in terms of flexural strength and permeability. The unit water content was varied so far as the stripping immediately after molding was possible.

Table 2 Mix proportions

Series	Number	W/C (%)	kg/m^3		$G_1 : G_2$ (Weight Ratio)	SP	PQ
			C	W			
A	1	25.0	400	100	7 : 3	0	0
	2	27.5		110			
	3	30.0		120			
B	4	17.5	400	70	7 : 3	C × 2.0%	0
	5	20.0		80			
	6	22.5		90			
C	7	17.0	400	70	7 : 3	C × 2.0%	C × 0.1%
	8	19.5		80			
	9	21.0		90			
D	10	21.3	400	85	7 : 3	C × 2.0%	C × 0.2%
	11	22.5		90			
	12	23.8		95			
E	13	20.0	350	70	7 : 3	C × 2.0%	C × 0.1%
	14	22.5		79			
	15	25.0		88			
F	16	20.0	350	70	10 : 0	C × 2.0%	C × 0.1%
	17	22.5		79			
	18	25.0		88			
G	19	20.0	350	70	5 : 5	C × 2.0%	C × 0.1%
	20	22.5		79			

2.3 Mixing

Mixing of concrete was made with a pan type mixer as shown in Figure 1.

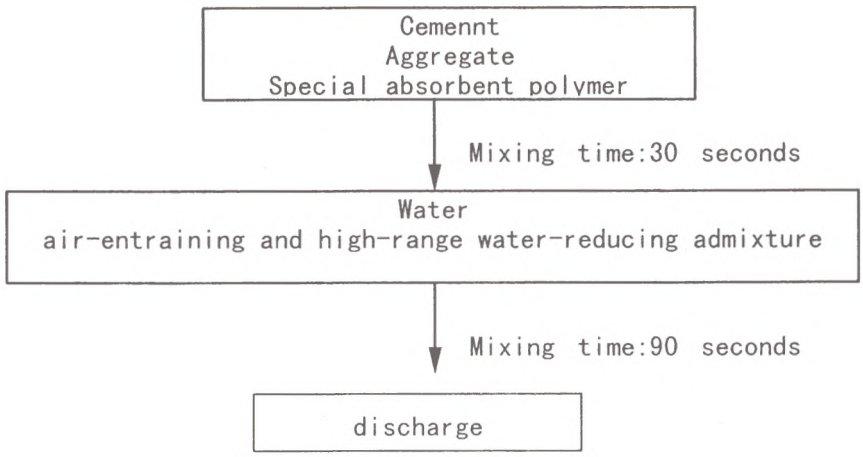

Figure 1 Method of mixing

2.4 Molding

Concrete was molded with a test machine made for the stripping immediately after molding (frequency of 3140 r.p.m, amplitude of 1.4 mm and pressure of 0.055N/mm^2). Blocks were shaped in a rectangular of 198 x 98 mm with a thickness of 80 mm.

2.5 Curing

Specimens were cured in the room atmosphere until the age for testing.

2.6 Test items

(1) Air void
Mass and dimensions of a specimen was determined after the demolding, and air void and fill factor were calculated according to the following formula.
Fill factor(%)=(mass of a block after demolding)/(theoretical mass of a block calculated from mixture proportion regardless of pore spaces) x 100
Air void(%)=100-fill factor
(2) Flexural strength test
Flexural strength was evaluated according to the test method specified in the Design and Construction of Interlocking Paving Blocks published by the Association of the Interlocking Paving Block Technology. The load was applied at the center of the specimen with a span of 16 cm. The rubber sheets were set at the loading and the supporting points to accept the load uniformly. The test was executed when the age of specimens became 28 days.
(3) Permeability test
Permeability was evaluated on the basis of the test method (constant water level method) specified in the Design and Construction of Interlocking Paving Blocks published by the Association of the Interlocking Paving Block Technology.

3. RESULTS AND DISCUSSIONS

3.1 Effects of air-entraining and high-range water-reducing admixture

Relationships between air void and flexural strength, and air void and permeability are shown in Figure 2 and Figure 3 respectively. Range of air void necessary for the stripping

immediately after molding showed no significant variation and was in the targeted range from 25% to 30 % when the air-entraining and high-range water-reducing admixture was added. Flexural strength and permeability were greatly affected by the addition of air-entraining and high-range water-reducing admixture and the resulting flexural strength and permeability were 4.5 N/mm^2 and 0.3 cm/s respectively. Thus it was proven that the addition of air-entraining and high-range water-reducing admixture led to the reduction of water-cement ratio of the pastes that combined the aggregate particles and resulted in an improvement of flexural strength without reducing the air void.

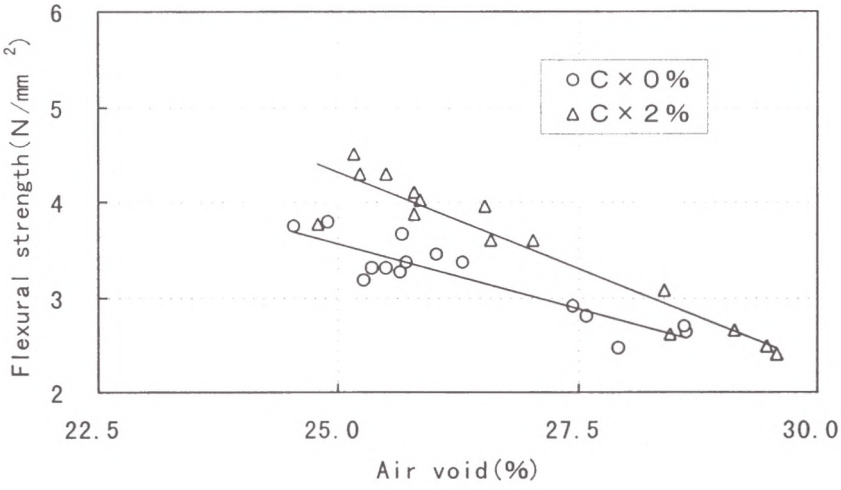

Figure 2 Effect of the addition of air-entraining and high-range water-reducing admixture on flexural strength

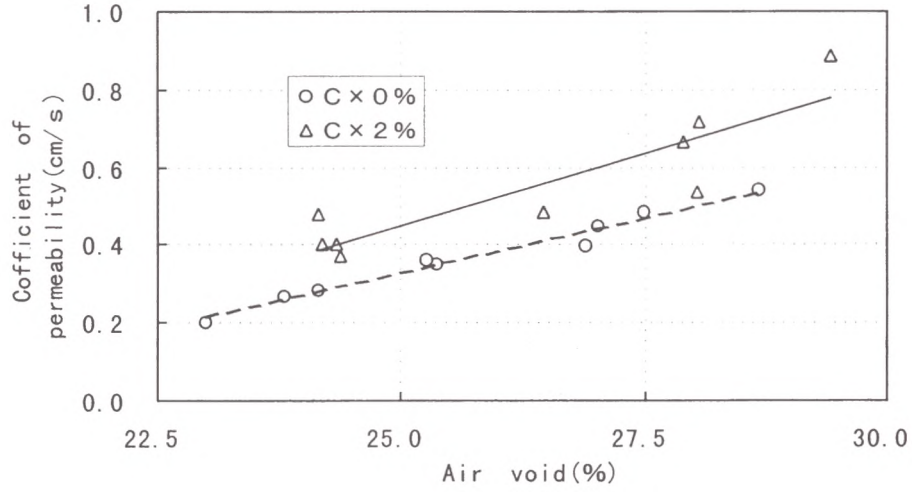

Figure 3 Effect of the addition of air-entraining and high-range water-reducing admixture on permeability

3.2 Effects of special absorbent polymer addition

Dosage of the special absorbent polymer was varied in 0, 0.1 and 0.2% with respect to the unit amount of cement. Relationships between air void and flexural strength, and air void and permeability are shown in Figure 4 and Figure 5 respectively. Range of air void necessary for the stripping immediately after molding showed no significant variation and

was in the targeted range from 25% to 30 % when the special absorbent polymer was added. Flexural strength showed an increase with an increase in dosage of the special absorbent polymer and was 5.0 N/mm^2 at an air void of 25% and 3.0 N/mm^2 at an air void of 30%, which implies that the special absorbent polymer addition can improve flexural strength. The reason of the improvement in flexural strength may be attributed to a gradual water release from the special absorbent polymer preventing cement from drying during the air curing. Permeability was nearly the same with the addition of the special absorbent polymer and but was as high as 0.3 cm/s at an air void of 25% and 0.8 cm/s at an air void of 30%.

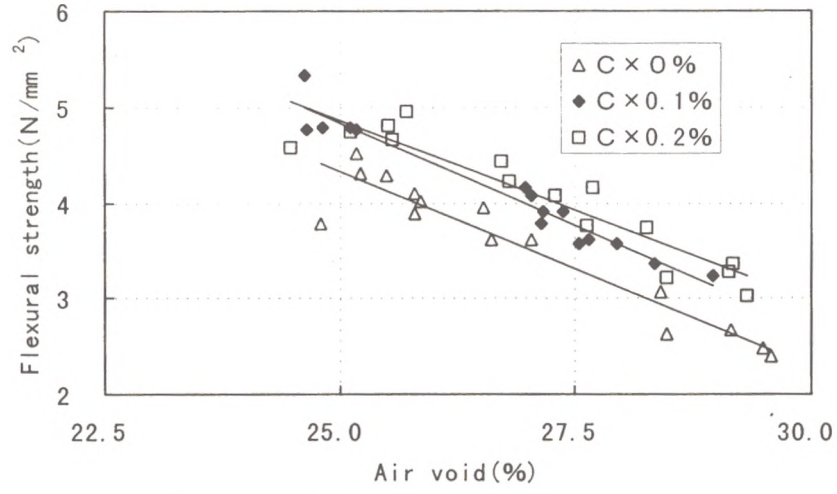

Figure 4 Effect of special absorbent polymer addition on flexural strength

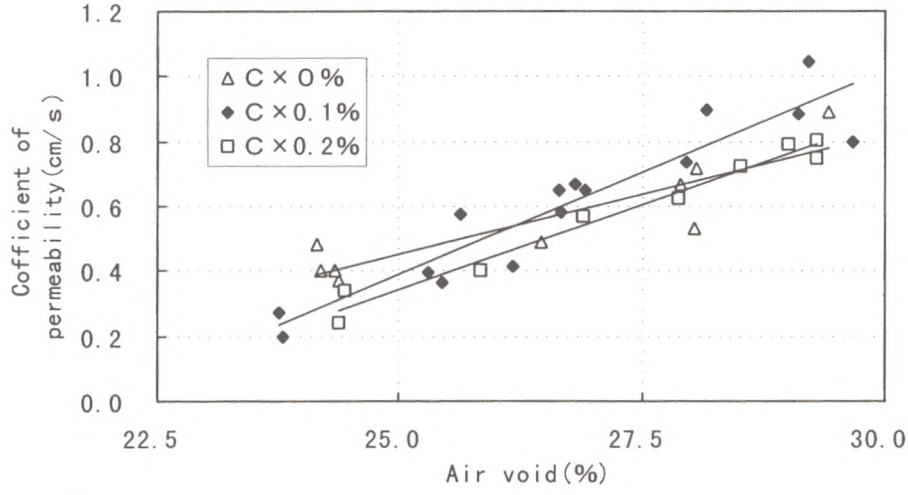

Figure 5 Effect of special absorbent polymer addition on permeability

3.3 Effects of unit cement content

Relationships between air void and flexural strength, and air void and permeability are shown in Figure 6 and Figure 7 respectively at unit cement content of 350 and 400 kg/m^3. Range of air void necessary for the stripping immediately after molding showed variation and was from 27% to 35 % at a unit cement content of 350 kg/m^3 and from 24 to 30% at a unit cement content of 400 kg/m^3. Flexural strength ranged from 2 to 4.5 N/mm^2 at a unit

cement content of 350 kg/m^3 and from 3 to 5 N/mm^2, larger than the former, at a unit cement content of 400 kg/m^3. However if compared at the same porosity of 28 %, in an allowable range for the stripping immediately after molding, flexural strength at a unit cement content of 350 kg/m^3 showed larger value of 4.5 N/mm^2. This implies that factors governing the strength of porous interlocking blocks are not simply restricted to the binder content but include an appropriate amount and coating thickness of the binder according the aggregate used. Permeability at a unit cement content of 350 kg/m^3 showed larger value, but the values were nearly the same if compared at the same air void. Permeability has a high correlation with air void as far as the same type of materials are used.

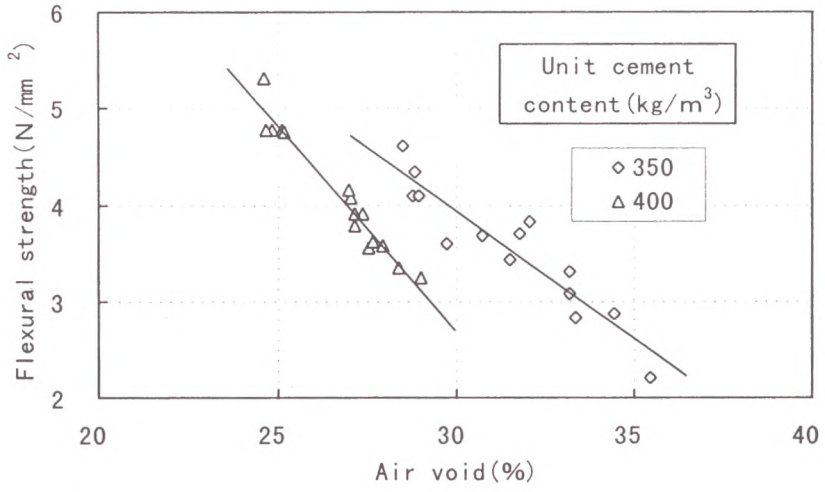

Figure 6 Effect of unit cement content on flexural strength

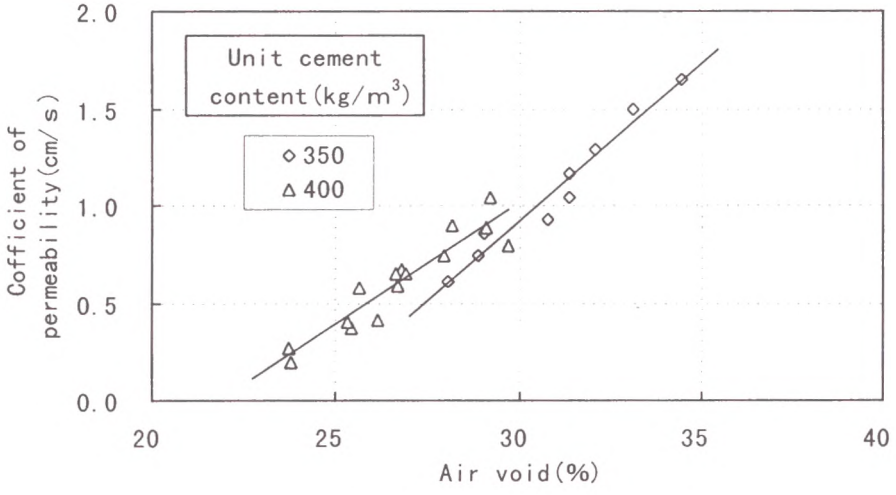

Figure 7 Effect of unit cement content on permeability

3.4 Effects of the grading of aggregate

Relationships between air void and flexural strength, and air void and permeability are shown in Figure 8 and Figure 9 respectively when coarse aggregate content was varied. The range of air void necessary for the stripping immediately after moldingtwas larger in the block using No. 6 aggregate (diameters ranging from 10 mm to 5 mm) only than that

using No. 6-No. 7 mixed aggregate, but no effects of the grading of aggregate were found in the dependency of flexural strength on air void. Permeability at the same air void was slightly larger in the block using No. 6 aggregate (diameters ranging from 10 mm to 5 mm) only than that using No. 6-No. 7 mixed aggregate. This may be attributed to an increase in water permeable path with an increase in the grading of aggregate.

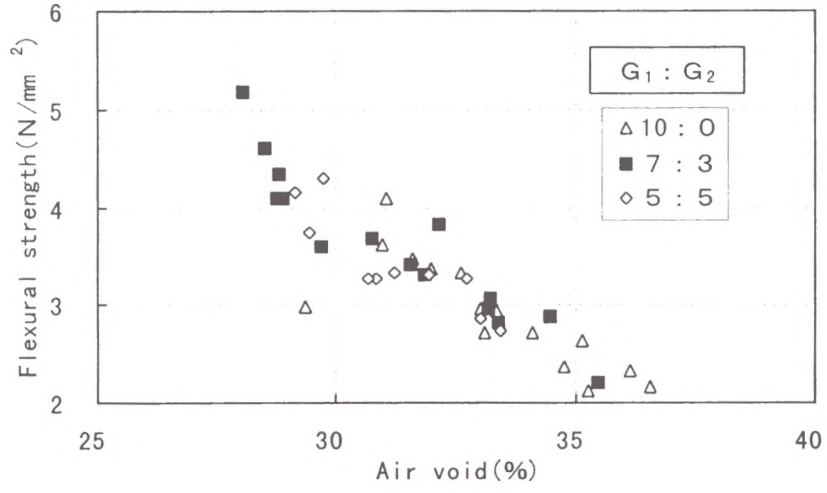

Figure 8 Effect of the grading of aggregate on flexural strength

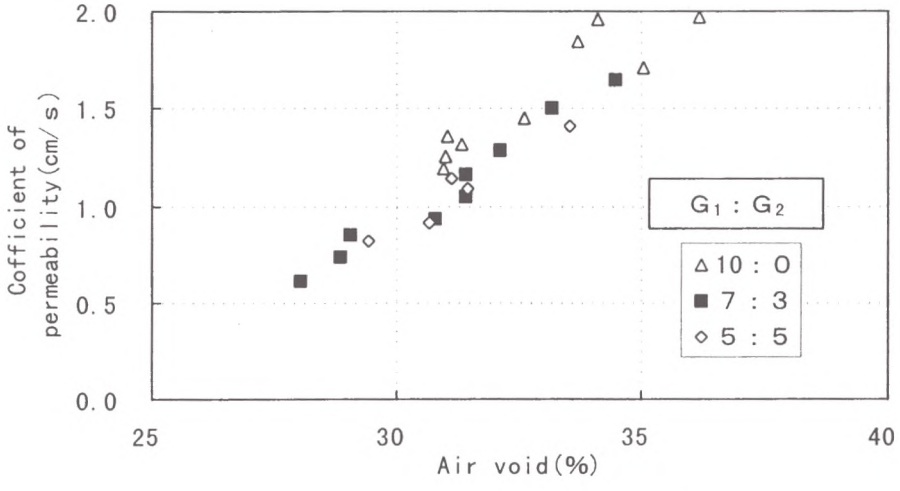

Figure 9 Effect of the grading of aggregate on permeability

4. CONCLUSION

(1) Addition of the air-entraining and high-range water-reducing admixture and the special absorbent polymer can improve flexural strength.
(2) Unit cement content has great influences on air void.
(3) Difference in the grading of aggregate changes the air void necessary for the stripping immediately after molding but has slight influence on flexural strength and on permeability at the same air void.
(4) Drainable paving block with satisfactory performances, such as flexural strength of

4.5 N/mm^2, permeability of 0.8 cm/s at an air void of 28 % or flexural strength of 5.0 N/mm^2, permeability of 0.3 cm/s at an air void of 25 %, can be manufactured using high-early-strength portland cement and admixture such as air-entraining and high-range water-reducing admixture and special absorbent polymer.