EVALUATION OF SUITABILITY OF A NEWLY DEVELOPED PIGMENT MORTARFOR INTERLOCKING BLOCK PAVEMENTS

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ABSTRACT

In the present paper, a new pigment mortar that can be easily used in filling irregular spaces between the interlocking blocks and manholes is developed. At the laboratory and field scale, the pigment mortar is tested for flow, setting time, compressive and flexural strengths, length change, workability, efflorescence, and color change. According to the test results, it takes 30 minutes for placing the mortar around a manhole, with almost the same color and texture to the original interlocking blocks. Also it is possible to engrave the shape of the interlocking block joints on the mortar surface before hardening. The compressive strength of the pigment mortar is 9 N/mm^2 after an hour from mixing. The pigment mortar makes the field working time shorter and prevents the dust and noise pollutions at construction site.

1. INTRODUCTION

The use of the interlocking blocks (IL blocks) in specific purposes, especially placing the IL blocks around specific shaped construction site like manholes, is quite difficult because of their specific size and shape. At such construction site, the IL blocks could not be perfectly adjusted in circular shapes and in corners of the manholes. They must be cut in required size and shapes according to the construction site. The cutting operation may be costly, and dust and noise pollution are occurred during the cutting operation. In the present paper, a newly developed pigment mortar which can be used easily in filling irregular space between the IL blocks and the manholes, is introduced. The pigment mortar is a mixture of an ordinary portland cement, pigments, an early setting agent, silica sand and lightweight fine aggregates. It is designed to achieve the same color and texture to the original IL blocks. The pigment mortar is prepared by adding 16.5% water (by mass to the dry mixture) into the dry mixture. Then the mixture is mixed with electric mixer until the mixture becomes uniform. The advantages of pigment mortar are its early-strength development and good workability. The pigment mortar is tested for flow, setting time, compressive and flexural strengths, and length change in the laboratory. At construction sites, the pigment mortar is placed around the different shapes of the frame of the manhole, and between IL blocks and garden stones, then tested for crack, efflorescence and color change in outdoor atmosphere for one year. According to the construction site test results, it takes 30 min for placing pigment mortar around a manhole, with almost the same color and texture to the original IL blocks. Also it is possible to engrave the shape of the IL block joints on the surface before hardening. The compressive strength of the pigment mortar is $9N/mm^2$ after an hour from mixing. The use of the pigment mortar makes the field working time shorter and prevents the dust and noise pollutions at construction site. This method may reduce the cost of construction compared to the conventional IL block paving.

2. MATERIALS

The materials are listed in Table 1. The pigment mortar is a mixture of an ordinary portland cement, pigments, an early setting agent, silica sand and lightweight fine aggregates. It was designed to achieve the same color and texture to the original IL blocks. The colors of pigments were black, red and yellow. Table 2 shows mix proportions of dry pigment mortar.

Table 1 Materials for Dry Pigment Mortar

Cement	Ordinary Portland Cement (OPC)	(Specific Gravity 3.16)
	White Portland Cement (WPC)	(Specific Gravity 3.16)
Sand	Silica Sand (S)	(Maximum Size 1.2mm, ρ_D=2.61)
	Lightweight Sand (LS)	(Maximum Size 1.2mm, ρ_D=0.74)
Pigment	Inorganic Agent (Pig)	(Iron Oxide)
Accelerating Agent (Acce.A)	Calcium Aluminate	(Specific Gravity 2.91)
Superplasticizer (SP)	β-Naphthalene Sulfate	
Retarder (Re)	Citric Acid	
Defoamer (Def)	Poly-ether Compound	

ρ_D : Specific Gravity in Oven Dried Condition

Table 2 Mix Proportions of Dry Pigment Mortar

(Weight percent)

Type of Mortar	Materials									
	OPC	WPC	S	LS	Pig	Acce.A	SP	Re	Def	Total
R	32.6	0	44.7	8.8	3.3	9.7	0.6	0.1	0.2	100.0
G	33.3	0	45.6	9.0	1.3	9.9	0.6	0.1	0.2	100.0
O	16.5	16.5	45.2	8.8	2.2	9.9	0.6	0.1	0.2	100.0

3. LABORATORY TESTS

3.1 Testing Procedures

(1) Preparation of Pigment Mortar

The pigment mortar was prepared by adding 16.5% water (by mass to the dry mortar) and mixed using an electric mixer (1,000rpm) for 2 minutes.

(2) Flow and Setting Time

The flow and setting time of the pigment mortar were measured according to JIS A 5201 (Physical Testing Methods for Cement) immediately after mixing.

(3) Compressive and Flexural Strengths

The mortar mixture was placed into 40x40x160mm molds and then the specimens were subjected for 20℃ and 90% relative humidity moist cure. Flexural strength was tested on 40x40x160mm beams and the broken parts of approximate size of 40x40x80mm were used for compressive strength. The tests were conducted according to JIS A 5201, and tested at 1,3,6 hours and 1,3,7,14 and 28 days.

(4) Drying Shrinkage and Expansion in Water

The specimens for drying shrinkage and expansion in water were prepared according to JIS A 1804 (Method of Rapid Test for Identification of The Alkali Reactivity of Aggregates). Before measuring drying shrinkage and expansion in water, the specimens were cured at 20℃ and 95% relative humidity for 7 days. Later, the specimens were stored at 20℃ and 50% relative humidity for measuring drying shrinkage, and immersed in the water at 20℃ for measuring expansion. The drying shrinkage and expansion in water of pigment mortar were measured at 0,1,3,7,14,21 and 28 days.

3.2 Results and Discussion

The general properties of pigment mortar are listed in Table 3. The flow of pigment mortar was designed to be constant at 200±10 for the purpose to place the mortar conveniently at construction sites. The setting time of pigment mortar was adjusted to be approximately 20 minutes. Therefore, the use of the pigment mortar reduces the working time with compared to the conventional procedures.

The compressive and flexural strengths vs. time of the pigment mortar are shown in Figures 1 and 2. The compressive and flexural strengths of the pigment mortar increase rapidly with time, and reach to 36.2N/mm^2 and 6.7N/mm^2 at the age of 7 days, respectively. There strengths are enough higher than JIPEA (Japan Interlocking Block Pavement Engineering Association) standard requirements, which are 32N/mm^2 for compressive and 4.9N/mm^2 for flexural. Also the pigment mortar shows an early-strength development as it reaches compressive strength of 9.3 N/mm^2 within one hour from mixing.

The drying shrinkage and expansion in water of the pigment mortar are shown in Figure 3. The drying shrinkage of the pigment mortar stored at 50% relative humidity increases with time, and becomes nearly constant at the drying period of 28 days. The drying shrinkage of the pigment mortar is 343x10^{-6} at the drying period of 28 days. This shrinkage is comparatively smaller than the ordinary cement mortar with the same water-cement ratio, because the pigment mortar contains lightweight sand. The expansion of the pigment mortar immersed in water is hardly recognized at the water immersion period of 28 days. Therefore, it is expected that no visible cracks should be developed in the pigment mortar placed in the construction fields due to its volume stability.

Table 3 General Properties of Pigment Mortar

Temperature	(°C)	20
W/Dry Mortar	(%)	16.5
Specific Gravity		1.85～1.90
Flow		200±20
Setting Time	(min)	20±10

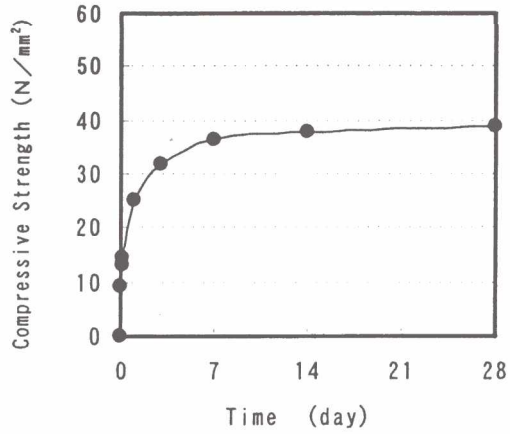

Figure 1 Compressive Strength vs. Time of Pigment Mortar

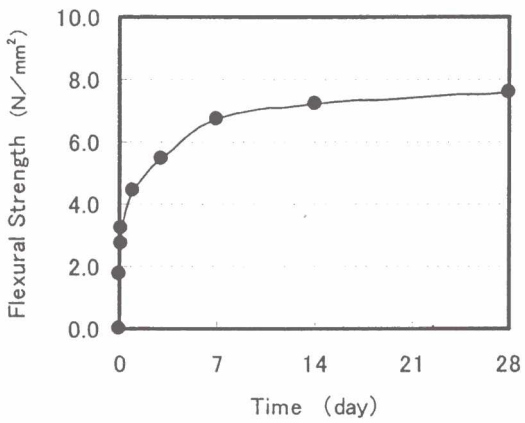

Figure 2 Flexural Strength vs. Time of Pigment Mortar

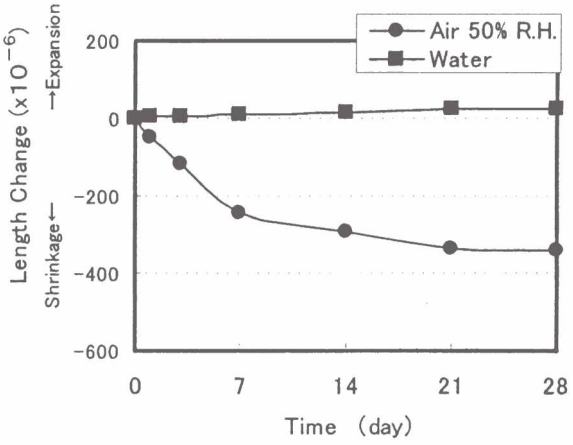

Figure 3 Length Change vs. Time of Pigment Mortar

4. FIELD TESTS

4.1 Test I

Figure 4 shows schematic view of the pigment mortar placed around the manhole. Test conditions are represented in Table 4. In this test, the pigment mortar type R (20kg by the dry mass) is used. The placement of the pigment mortar is done according to the following steps.

(1) Spraying kerosene to the inside of IL blocks
(2) Cutting the bar for forming dummy joint (shown in Figure 5)
(3) Spreading cushion sand in 2 cm thickness, and spraying water
(4) Mixing the pigment mortar
(5) Pouring the pigment mortar around the manhole
(6) Pressing the bar on the surface of the pigment mortar
(7) Pulling the bar form the pigment mortar

At the construction site, working hours, setting time and workability of the mortar were examined. After the pigment mortar hardened, crack, efflorescence and color change were observed.

Table 4 Test Conditions

Atmosphere Temp.	Executed Area	Size of IL Block	Outside Diameter of Manhole
18 °C	0.33 m^3	240x120x60mm	ϕ 705mm

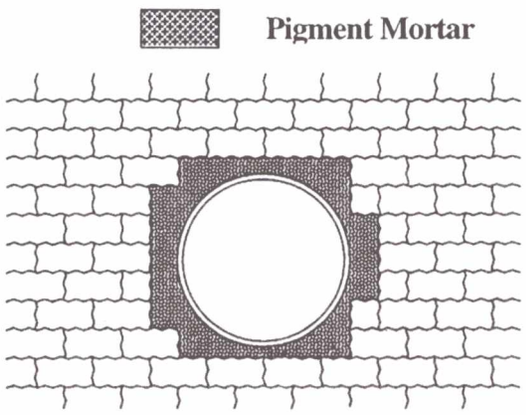

Figure 4 Location of Pigment Mortar at Construction Site

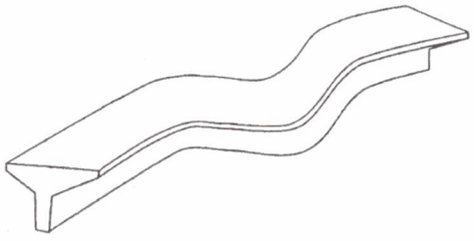

Figure 5 A View of Bar Used for Forming Dummy Joint

Table 5 shows working time of the construction processes. The pigment mortar was placed easily around the manhole in relatively shorter working time compared to the conventional cutting procedures. The texture of the hardened pigment mortar was similar to the IL blocks around. When the pigment mortar is wet, the color is similar to the IL blocks. However, when it is dried, the color of the pigment mortar is brighter than the IL blocks. The difference is caused by the volume fraction of paste in the pigment mortar is much larger than the paste of IL block. Therefore, it is needed to adjust the color of mortar more darker.

After the pigment mortar hardened, the efflorescence appeared on the surface in early days. It may be caused by the accelerating agent which contains calcium aluminate. The efflorescence can be cleaned by a chloride detergent. After two years from the test, there is no visible crack appeared on the pigment mortar. Photos 1 and 2 show the view of the pigment mortar immediately after placing and after two years, respectively.

Working time of the pigment mortar method is 30 min for each manhole, which is less than half as compared to 74 min for conventional cutting method. Furthermore, construction cost for the pigment mortar method is lower than conventional cutting method by more than 1,000 yen as given in Table 6. Also the pigment mortar prevents the dust and noise pollutions at construction site.

Table 5 Working Time at Construction Site

No.	Processing Steps	Time (min)
1	Spraying the Kerosene	2
2	Cutting the Bar	7
3	Spreading the Cushion Sand	3
4	Mixing the Pigment Mortar	4
5	Pouring the Pigment Mortar	4
6	Pressing the Bar	5
7	Pulling the Bar	3
Total		30

Table 6 Comparison of Working Cost between the Conventional Cutting Method and the Pigment Mortar Method

Procedures	Contents	Quantity	Unit Cost	Cost (yen)
Conventional Cutting	IL Block (cut and laid around manholes)	16 piece	100 yen/piece	1,600
	Personal Expenses	0.15 day	28,500 yen/day	4,275
	Rental Charges of Concrete cutter	0.15 day	3,000 yen/day	450
	Disposal of Waste Fragments	20 kg	10 yen/kg	200
	Total			6,525
Placing Pigment Mortar	Pigment Mortar	20 kg	175 yen/kg	3,500
	Personal Expenses	0.0625 day	28,500 yen/day	1,781
	Rental Charges of Electric Mixer	0.0625 day	1,500 yen/day	167
	Total			5,448
	Note : cost per each manholes (ϕ 705mm)			

4.2 Test Ⅱ

The pigment mortar type G is applied in the gap between the cut blocks and the manhole having irregular shape as shown in Photo 3. 15kg of the dry pigment mortar was used for each manhole. The atmospheric temperature during this test was 12℃. The dummy joint was not used for this work. As the same as test Ⅰ, workability and the properties of hardened mortar were examined.

The mortar could be poured and filled easily into the gap between the blocks and manhole. It takes 15 min for each construction site. The setting time of the mortar is about 40 min, because the temperature was lower than the designed temperature. Photo 4 shows the surface condition of the pigment mortar one year after the test.

4.3 TestⅢ

The pigment mortar type O was used between IL blocks and garden stones in a public utility facility. The construction site is leaned and divided into two areas. The inclination of each area is about 2 and 8 degrees. The ordinary cement mortar is applied as the base mortar 3 days before the test. Before placing the pigment mortar, the emulsion of vinyl acetate/ethylene copolymer is sprayed on the surface of the base mortar. Afterward the pigment mortar was poured and leveled on the base mortar with the height of 2 cm. At the area with higher inclination, silica sand with the maximum size of 1.2mm was added to the pigment mortar at the time of mixing in order to prevent the flowing after the placement. The dummy joint was formed with concrete cutter after the hardening of mortar.

For the lower inclination area, the pigment mortar was placed easily as Tests Ⅰ and Ⅱ described above. However, the silica sand added mortar of higher inclination area was difficult to mix, and took much time in placing and leveling. Photos 5 and 6 show the surface condition of the pigment mortar two years after the test.

5. CONCLUSIONS

(1) The use of pigment mortar is suitable for the sites where are difficult to cut irregular space of the IL blocks, and that is possible to reduce the working time.

(2) The original color of the pigment mortar is desirable to be slightly darker than the original IL blocks by adjusting the paste volume.

(3) The efflorescence appears in early days, because of accelerating agent made from calcium aluminate, however it can be cleaned by a chloride detergent.

(4) By adding sand into the pigment mortar mixture, it is able to use in the sites with high inclination, however this needs much time for placing and leveling.

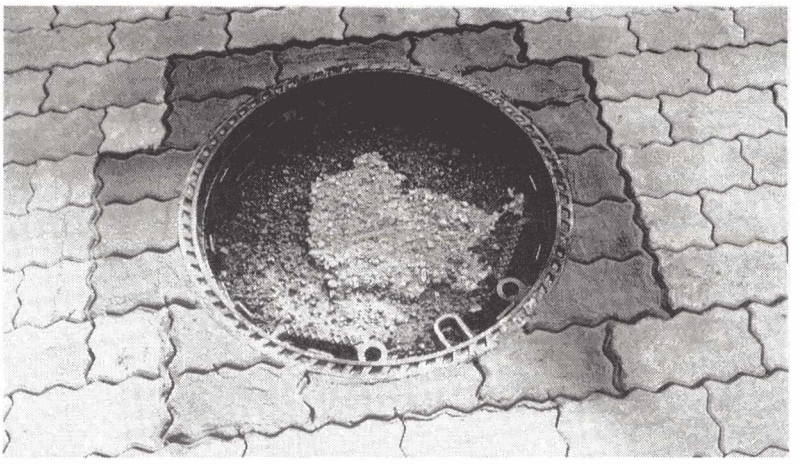

Photo 1　View of Pigment Motar Immediately after Placing

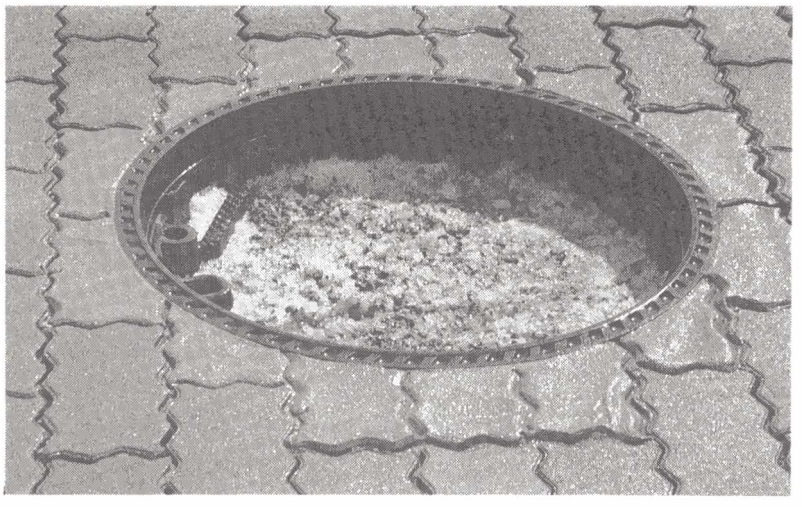

Photo 2　View of Pigment Motar Two Years from Placing



Photo 3　Gap between Blocks and Manhole before Test



Photo 4　View of Test Ⅱ Site One Year from Placing

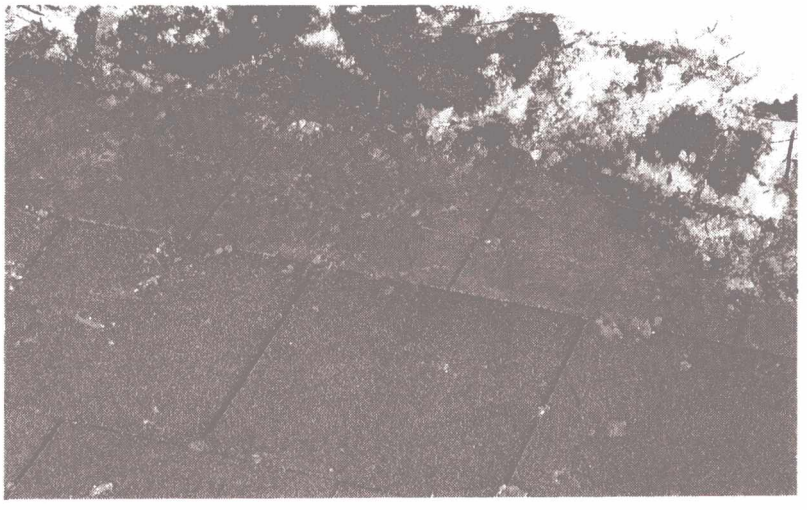

Photo 5　View of Test Ⅲ Site One Year from Placing (Lower Inclination)

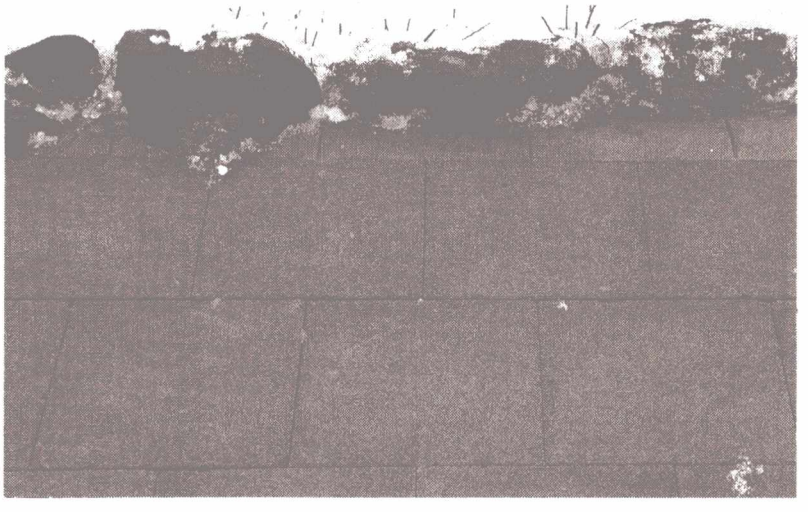

Photo 6　View of Test Ⅲ Site One Year from Placing (Higher Inclination)