CONSIDERATIONS ON POWDER POLYMER FLAME SPRAYED CONCRETE BLOCKS

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SUMMARY

When the concrete block is used for the general traffic roads and community roads, although the white concrete block is designed to be used for the lane mark, it may not be adopted since the whiteness, reflectance ratio, etc do not satisfy the standard of traffic paint in Japan. The result of the manufacture and evaluation of concrete block of which the surface is coated by the mixture of white polymer and fine glass grain by the powder polymer flame spray method could satisfy all the standards of whiteness, reflectance ratio, weathering resistance, abrasion amount, etc. In addition in the test pavement on the general traffic roads, it was confirmed that there is no damage of concrete block and it can withstand enoughly the application.

Since the concrete block with unique color tone can be obtained when the powder polymer flame spray method is used, various samples were manufactured and evaluated in order to apply to the pavement covering to pedestrian. A clean color which cannot be obtained by the normal concrete block using pigment is obtained and versatile surface finish is possible. Even after two years since test execution, a color fading is less than normal concrete block and the efflorescence phenomenon did not occur.

By using the powder polymer spray method, the adaptation to the lane mark of traffic roads became possible and in the footway pavement, the supply of the block with superior beautifulness which satisfy the requirement of designer became possible.

1. INTRODUCTION

The concrete block paving in Japan is mainly accepted for a walker's space such as a footway, park, approach of architecture, etc. However, recently the block pavements are extending to traffic roadways. In the traffic roadways, there are many cases where the concrete blocks are used for the intersection in terms of braking ability, visibility of driver and road surface transformation countermeasure of asphalt pavement. Since lane marks of pedestrian crossing, stop line, center line, etc. are required at the intersection, a white block is necessary.

A block formed by two layer (Fig.1) is generally used in Japan and more is a case where a white block using white cement on the surface layer is adopted for the test purpose. However, it may not be adopted since it does not satisfy the standard in that the whiteness is poor compared with traffic paint mixed with fine glass grain usually used in Japan and mixing of fine glass grain is difficult. In addition, after block pavement has been completed, a lane mark is provided by coating traffic paint further on the white block but it is not natural and lacks in beautifulness and durability. Although concerning the application of concrete block to the lane mark, it is required to investigate the whiteness and return reflection factor, it is difficult to satisfy the Japanese standard unless the composite with other material is considered.

On the other hand, for the pavement covering the pedestrian, the importance is put on the beautifulness rather than function. Although a concrete block colored by pigment is widely used there are problems of efflorescence and fading. In addition, depending on the designer, bright colored blocks are required. However, when considering these are cement products, it is difficult to solve these problems. To satisfy thes requirements, it is considered that the surfa of a concrete block is covered by other mater als but the correspondence is very difficult because a coating film is too thin by usual coated method and lacks in durability and it requires much time to finish.

In order to resolve above-mentioned proble it was tried to apply the powder polymer flam spray method. This report evaluates the perfo ance as a lane mark of traffic roads of concr block on which surface the powder polymer is sprayed and at the same time tries to supply new type of block for another application wit excellent beautifulness.

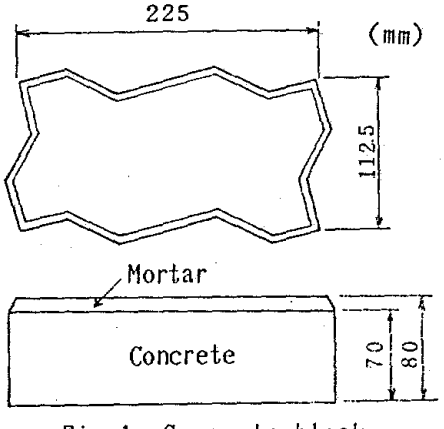

Fig.1 Concrete block

2. POWDER POLYMER FLAME SPRAYING METHOD

The powder polymer flame spraying is a met to eject the powder polymer by melting with h temperature flame from a spray gun and spray the surfaces of an article after preheating t surface of an article at 100 -150°C as shown

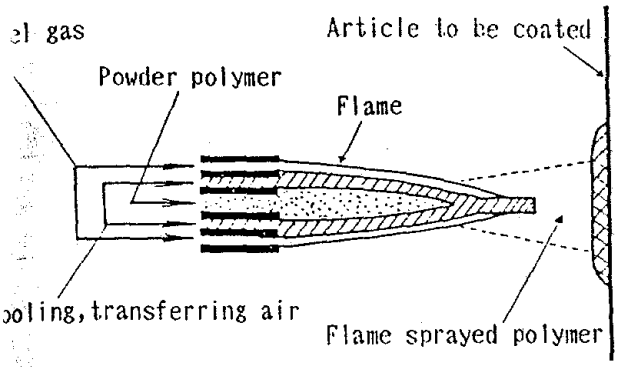

Fig.2 Powder polymer flame spraying method

Fig.2. The sprayed powder polymer generates melting or bonding reaction properly and sprayed film is formed by being cooled naturally. As the fuel gas of heat source, the combinations of oxygen and acetylene, oxygen and propane gas and air and propane gas are used, the cheapest combination of air and propane gas is adopted.

The flame spraying works is performed by selecting properly flow rate of air, propane gas, powder polymer and operating speed of spray gun. 0.7mm of sprayed film thickness is aimed and allowable width is set at ± 0.2mm. A pin hole occurs at the high probability for less than 0.3 mm and there are problems more than 1.2mm that even finish is difficult, painting needs much time and the cost becomes high.

The following characteristics are required for the powder polymer used for flame spraying.

* When the powder is supplied to the flame spraying gun, the transportability by air is superior.
* The difference between on temperature of melting by flame and thermal decomposition temperature is large.
* There is no degradation such as carbonation and discoloration when exposed to high temperature.
* The weather resistance is excellent.

Based on the above-mentioned facts, the E.V.A. (ethylene vinyl acetate copolymer) was used as powder polymer.

The white concrete block used as a lane mark of traffic roads requires to enhance the reflection ratio of the surface and improve the visibility at night. The fine glass grain (grain size : 105-840μm) specified by JIS R 3301 was used by mixing the white powder polymer. In addition, as the extending agent of polymer or to enhance the skid resistance of the surfaces, fine silica sand (grain size: 100-400μm) was mixed with polymer and used.

The spray material mixing ratio of white block for traffic roads used in the test is shown in Table 1.

Coloration of the powder polymer is possible and red, yellow, brown, green, blue, white, black, orange, etc can be selected depending on the uses. In order to produce the pavement by putting stress on the beautifulness rather than function, a flame spraying block was manufactured concerning various colored powder polymer and their mixtures. In addition, a representative one is executed and time elapsing change of color was measured.

Table 1 Mixing ratio of spraying material (for lane mark)

		Mixing ratio (%)	
		Weight	Volume
Type I	White powder polymer	83	93
	Fine glass grain	17	7
Type II	White powder polymer	42	65
	Silica sand	41	25
	Fine glass grain	17	10

3. TEST METHODS

3-1 Accelerated yellowness test (JIS K 5400)

This is a test to evaluate the whiteness of white coated film. A tendency of yellowing in the dark and humid air is expressed as yellowness by calculating from the tristimulus values (X,Y,Z) obtained by measuring colors of coated film through the accelerated test.

3-2 45° and 0° diffuse reflectance test (JIS K 5400)

This is a test to measure the brightness of the white coated film. The reflectance at the time of light receiving angle 0° with the angle of incidence of 45° is measured and expressed as percentage.

3-3 Return reflectance test

This is a test to measure the reflectance of coated film by light. It is measured at the time of light receiving angle of 86° 40′ with the angle of incidence of 88° and expressed as percentage.

3-4 Accelerated weathering test (JIS K 5400)

A sunshine carbon arc type weather meter is used. By irrigating a light from a carbon arc lamp and spraying a mist of water at a fixed interval on the specimen, the degradation of coated film is examined. 60 hours of test time was adopted based on the police standard.

3-5 Alkali resistance test (JIS K 5400)

The specimen is immersted in satulated solution of calcium hydroxide for 18 hours and the degradation of coated film is observed and when no blistering, cracking and peeling are confirmed, it is assumed to be normal.

3-6 Adhesive test

The adhesive strength between concrete block surface and polymer layer is measured. By using an adhesion tester, the measurement was made by assuming a test area as 10 * 10 = 100 cm^2.

3-7 Skid resistance test (ASTM E 303-69T)

The skid resistances of the surface in measured by using the British Pendulum Skid Resistance Tester. The surface is rubbed by a rubber slider installed at the end of the pendulum and friction resistance is expressed as the skid resistance value (B.P.N.). The test was conducted under both dried and humid surface conditions.

3-8 Abrasion test

(1) Raveling test (Asphalt Pavement Requirement)

A wheel equipped with a tyre chain hits to surface of specimen and separates and tears the surface. The test time is 180 minutes and wear amount is expressed by cross sectional area (cm^2).

(2) Grinding test

A concrete block is placed on the rotating disc (30rpm) and the surface is abrade by spraying abrasives (carborandam). The test time is 100 minutes and wear amount is expressed by worn depth (mm).

(3) Abrasion test by abrasion-paper method (JIS K 5665)

A specimen is placed on the rotating disc and a wearing wheel around which an abrasive paper is runs on the specimen and abrade the surface. The wear amount was expressed by weight decrease (mg) after 100 revolutions.

3-9 Test pavement on general traffic roads.

It was adopted as the test pavement of the government office work of Tama City, Tokyo. It is the intersection of metropolitan where many light trucks and automobiles pass and Type I and II are executed for the pedestrian crossing and stop line. As a tracking investigation, external observation is being carried out.

3-10 Coror change measurement by outdoor exposure

A concrete block is actually executed and a color before execution and after two years was measured. a color of the block surface is expressed by the Hunter (L,a,b) Diagram and a color difference due to outdoor exposure was calculated.

4. TEST RESULTS AND CONSIDERATIONS

4-1 Accelerated yellowness test (Table 2)

A tendency of yellowing of white coated film is tested by the accelerated test and both Type I and II satisfied the standard value. It was indicated that the whiteness of coated film can be maintained enoughly under the natural environment.

Table 2 Results of accerelated yellowness test

	Yellowness
Type I	0.09
Type II	0.09
JIS K 5665	0～0.1

4-2 45°and 0°diffuse reflectance test (Table 3)

This tests the brightness of coated film and both Type I and II satisfied the standard value. It was indicated that the polymer is not subjected to heat degradation due to flame spraying and has enough brightness as the coated film.

The reflectance of Type II into which the silica sand is mixed is smaller than Type I. This is considered to be due to the flatness of the surface.

Table 3 Results of 45° and 0° diffuse reflectance test

	45° and 0° diffuse reflectance (%)
Type I	88
Type II	77
JIS K 5665	More than 75

4-3 Return reflectance test (Table 4)

By mixing the fine glass grain, the visibility of block surface at night can be enhanced. It was confirmed that Type II is the same degree as normal traffic peint and the visibility of Type is superior.

Table 4 Results of return reflectance test

	Return reflectance (%)
Type I	16
Type II	12
Traffic paint	10～12

4-4 Accelerated weathering test (Table 5)

The weather resistance is evaluated by the accelerated test and it was indicated that no abnormality of the status of coated film of Type I and II and the weather resistance is superior.

Table 5 Results of accelerated weathering test

	External appearance of coated film
Type I Type II	The discoloration, cracking, peeling, decrease of gloss and blistering do not occur.
JIS K 5665	The discoloration, cracking, peeling, decrease of gloss and blistering do not occur.

4-5 Alkali resistance test (Table 6)

This tests the alkali resistance of coated film and it was indicated that there is no abnormality of coated film of Type I and II and enough alkali resistance is provided.

Table 6 Results of alkali resistance test

	Alkali resistance
Type I Type II	No abnormality
JIS K 5665	No abnormality

Adhesive test (Table 7)
This tries to measure the adhesive strength ween concrete block surface and polymer. Most tested concrete block has broken in the mor- of concrete block rather than the adhesive face. This means that the adhesive strength tween concrete and coated film is more than asured value and the adhesive force of polymer y be enough.

Table 7 Results of adhesive test

	Adhesive strength (kgf/cm²)
Type I	More than 16.8
Type II	More than 19.8

*The concrete block has broken in the mortar

-7 Skid resistance test (Table 8)
This measures the skid resistance value of he concrete block surface. Although a value ore than equivalent to the normal concrete lock is indicated under dried surface condition a lower value is indicated to the contrary nder humid condition. Since Type I 's surface s flat, a thin layer of water is generated etween surface and rubber slider under humid ondition and the surface becomes slidiable. lthough Type II is not so smooth as Type I , he same trend appears. Since a value of traffic aint is low and other physical properties (whiteness, reflectance) are important, an actual status is that any special improvement is ot added.

able 8 Results of skid resistance test

	Skid resistance value (BPN)	
	Dry	Wet
Type I	95	36
Type II	96	66
Normal concrete block	91	81
Traffic paint	--	35~40

4-8 Abrasion test (Table 9)
The result of rabeling test and concrete grinding test shows that abrasion amount of both Type I and II is very smoll. In addition, it can be confirmed that the abrasion-paper test satisfies the standard value enoughly. Although it differs from actual use condition, it is considered that the abrasion proof is superior by conducting the test with three kinds of method. This may be due to the strength and proper elasticity of polymer itself.

Table 9 Results of abrasion test

	Ravering test (cm²)	Grinding test (mm)	Abrasion-paper test (mg)
Type I	0.06	0.07	14
Type II	0.04	0.09	21
Normal concrete block	2.38	1.36	--
JIS K 5665	--	--	Less than 200

4-9 Test pavement on general traffic roads.
Although it elapsed more than one year after putting in use, there is no abrasion and no damages such as peeling, dent, and cut-off. It was confirmed that both Type I and II can be used as the concrete block for lane mark.
4-10 Color change measurement by outdoor exposure (Table 10)
Measurement of color before execution and after two years of normal concrete block colored pigment and concrete block sprayed by colored powder polymer was conducted and compared.
Hunter (L,a,b) Diagram consists of a cubic color space composing of a plane by Cartesian coordinates of abscissa 'a' and ordinate 'b', and axis 'L' of expressing the brightness in vertical direction as shown in Fig.3. An intersecting point of axis 'a' and 'b' is a coordinate of non-color (white, gray, black) and + side of axis 'a' indicates an area of red, - side indicates an area of green, + side of axis 'b' indicates an area of yellow and - side indicates an area of blue and as it sets apart from the original points, the colors increses.
It can be found from Table 10 that the same tint of flame sprayed concrete block is clearer than normal concrete block. In addition, even after two years of execution, a change of tint resulted in less.
The others, there is no damage such as peeling, dent, and cut-off and naturally efflorescence did not occur.
This concrete block using colored polymer can express various and clear color tone which can not be realized by pigment and the application to the pavement which covers the pedestrian such as shopping center and park and it can be said that it has a superior beautifulness because change of color tone is less and efflorescence does not occur.

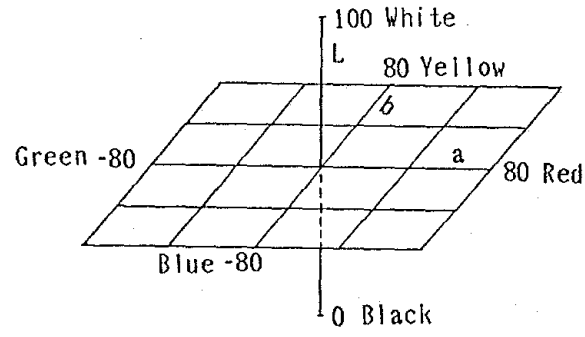

Fig.3 Hunter(L,a,b) diagram

Table 10 Results of color measurment before execution and after two years

		Red		Green		Yellow		Brown		White		Blac	
		Befor	After	Befor	After	Befor	After	Befor	After	Befor	After	Befor	Af
General products	L	29.3	35.2	44.5	42.7	54.4	46.4	26.6	33.6	66.6	51.4	27.0	3
	a	12.5	5.7	-10.6	-3.1	8.2	2.6	3.7	1.4	0.0	0.1	0.3	-
	b	7.5	4.2	11.0	5.0	26.0	10.8	4.4	2.8	7.3	5.1	1.4	
	ΔE	--	9.7	--	9.7	--	18.1	--	7.6	--	15.3	--	
Flame sprayed products	L	46.3	44.1	72.4	69.7	70.9	68.8	24.3	27.9	87.8	82.6	21.6	2
	a	37.2	34.7	-22.6	-20.0	2.3	2.0	2.6	1.8	-0.6	-0.4	0.0	
	b	24.2	23.0	20.0	17.2	38.2	34.1	4.4	3.4	2.8	2.9	1.0	
	ΔE	--	3.5	--	4.7	--	4.6	--	3.8	--	5.2	--	

Befor=Befor execution After=After two years

5. AUTOMATION OF FLAME SPRAY DEVICE AND VERSATILITY OF FINISH

Although the powder polymer flame spray method is described in the chapter 2, there are the problems that uneven painting occurs, work efficiency is poor and that it is not favourable in terms of safety for finishing by manual work using a flame spray gun only. In order to solve these problems, an automatic flame spray line was manufactured. A composition of the line is shown in Fig.4. The concrete block moves on the conveyor and after the surface temperature is raised by a heater, the concrete block is subjected to flame spraying by large capacity gun 1 and finishing gun 2 which reciprocates at right angle direction against moving direction. Setting of each machine composing this device is variable and each machine is arbitrarily adjusted depending on the kind of product and operation.

A flame spraying gun can be used not only for polymer but also by mixing granular articles such as fine sand and fine glass grain and a finishing gun 2 can spray only granular article with flame. By selecting granular article properly, the color and physical property of the surface can be made versatile easily.

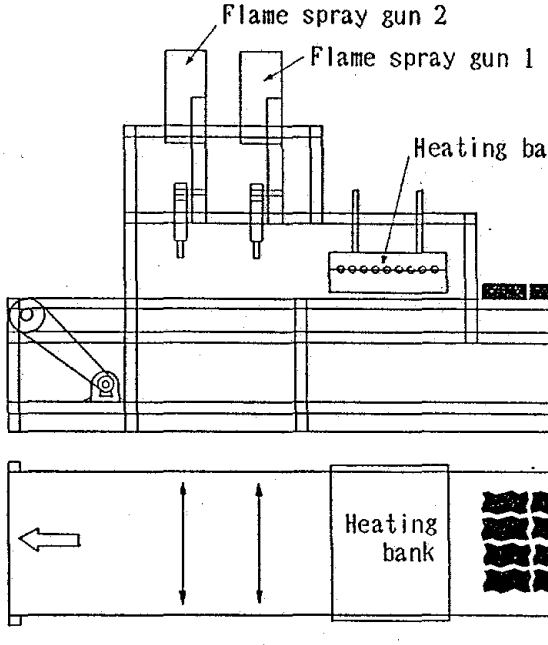

Fig.4 Automatic flame spray line

6. CONCLUSIONS

For the deployment of the concrete block the traffic roads, the development of white block for lane mark of which whiteness and reflectance of the concrete block surface a improved is one problem. The powder polymer flame spray method is adopted as the surface coating method of concrete block and the ph cal property test of manufactured concrete was excuted and evaluated. In addition, bec the concrete block which has unique color t can be obtained when the powder polymer fla spray method is used, various samples are m factured and evaluated to apply to the pave covering the pedestrian.

The result of the test is shown below;

(1) The whiteness and reflectance ratio of concrete block surface satisfied the standa and it was confirmed that it has larger vis ity than traffic paint.

2) The concrete block satisfied the standard in the accelerated weathering test and alkali resistance test and it was confirmed that enough durability is provided. In addition, adhesive between concrete block surface and polymer layer is enough.

3) The skid resistance value under humid condition of the concrete block using fine glass grain and powder polymer is small and is the same degree as the traffic paint. However, when silica sand is mixed, it was found that the skid resistance value is largely improved.

4) As a result of the abrasion test of the surface by three kinds of the method, superior abrasion resistance was shown and the standard value was satisfied enoughly.

5) The concrete block was not damaged by the test pavement in the general traffic roads and it was confirmed that the concrete block was enoughly suitable for the application.

(6) A color of the concrete block manufactured for the footway is measured and a clean color which cannot be obtained for the normal concrete block using pigment is obtained. In addition, after two years of test execution, the result was such that color fading was less than the normal concrete block. In addition, the efflorescence phenomenon which affects the beautifulness of concrete block did not exist.

As mentioned above, the concrete block of which the surface is coated by powder polymer satisfied all the standards of the traffic paint in Japan in terms of whiteness, reflectance ratio, weathering resistance, abrasion resistance, etc.

In Japan although there are many cases when the application of concrete block to traffic roads pavement is trially done at the intersection, there were many cases when the concrete block was not adopted because the white concrete block which was used for the lane mark did not satisfy the standard of traffic paint. We are happy if this problem is solved by this research and the concrete block prevails widely for the traffic roads hereafter.

In addition, we consider that the applicable range is wide for the pavement covering the pedestrian. Because clean and unique color tone can be expressed, versatile surface finish is possible and there is no efflorescence phenomenon, it can satisfy the requirement of the designer. We consider that it can enoughly emulate with a tile and concrete flag in terms of design and can contribute the prevailing of concrete block.