Study on preventing efflorescence to improve beauty of concrete.*[1]

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Abstract

Appearence has become an essential issue in concrete engineering these days. The esthetic of concrete is affected by its design, color, surface finish and surface cracking. The purpose of this study is to test and analyze the factors causing efflorescence on concrete surface in order to prevent efflorescence to improve beauty of concrete. Experiments were carried out using model specimens 10×10×20 cm in size with different curing conditions and internal factors. The resulting data were analyzed to find the relation between such factors as coefficient of moisture and the ratio of efflorescence-affected area. The most influential factor was found to be the coefficient of moisture, followed by the water-cement ratio.

1. INTRODUCTION

Esthetic appearance is now an important issue in concrete engineering. The esthetics of concrete are affected by the design, color, surface finish and surface cracking of the concrete. The purpose of this study is to experiment and analyze the factors causing efflorescence[1)] on concrete surface.

2. METHOD

The procedure used in this study of factors causing efflorescence is shown in Fig. 2. 1. The size, water-cement ratio, and unit weight of cement for the experimental specimens is shown in Table 2. 1. The specimens were of colored concrete. The mix proportion, properties, and strength of the concrete are shown in Table 2. 2. The mix proportion was varied according to unit cement weight and water-cement ratio so as to maintain the air content at 4.5±1 %. Slump data were measured for reference purposes. Photographs of the experiments are shown in Photos 1, 2, and 3. After mixing, a color admixture was added to the fresh base concrete and carried into the curing room, where the relative humidity was 80 %. After a day, the weight and surface moisture ratio[2)] were measured. In order to record the initial condition of the concrete surface, photographs were taken. The evaluation[3)] of

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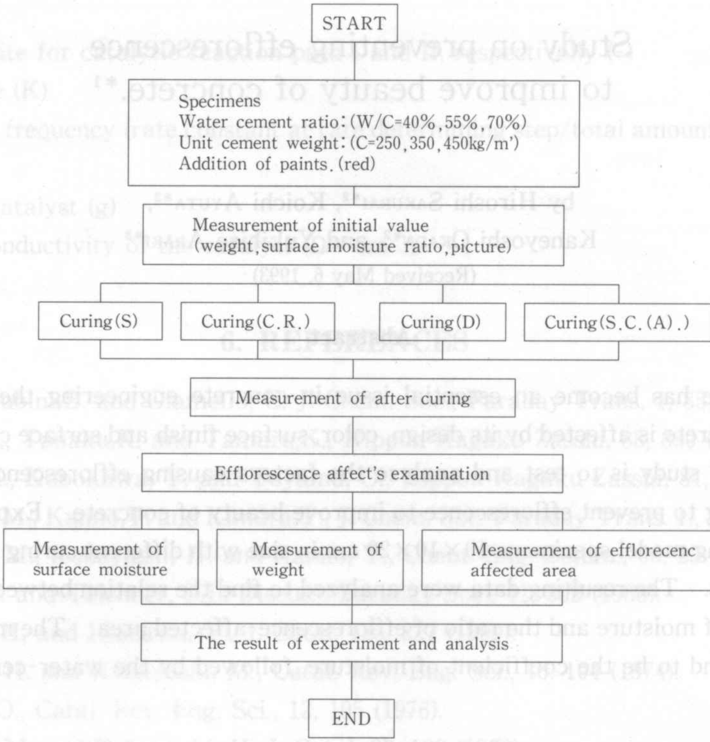

Fig. 2. 1 Flow of the study on preventing efflorescence to improve beauty of concrete

Table. 2. 1 The size, water-cement ratio and unit weight of the experimental specimens

Size of specimens	10×10×20cm
Water cement ratio : W/C	40%, 55%, 70%
Unit cement weight : C	250, 350, 450 kg/m³

moisture conditions is shown in Table 2.3. The coefficient of moisture (CM) of the specimens were decided by calculating Equations (2.1) and (2.2).

$$CM = \frac{1}{M} \times 100 \quad \cdots\cdots\cdots \text{Equation (2.1)}$$

where, M is linear regression result of Table 2.3 and the next equation;

$$M = 0.03333EC + 4.333 \quad \cdots\cdots\cdots \text{Equation (2.2)}$$

where, EC is environmental condition.

The specimens were cured until seven days of age under standard curing conditions, in a curing room, in a dry room, and in a special curing room as shown in Table 2.3.

At 28 days, the specimens were set up in an efflorescence measuring apparatus. The

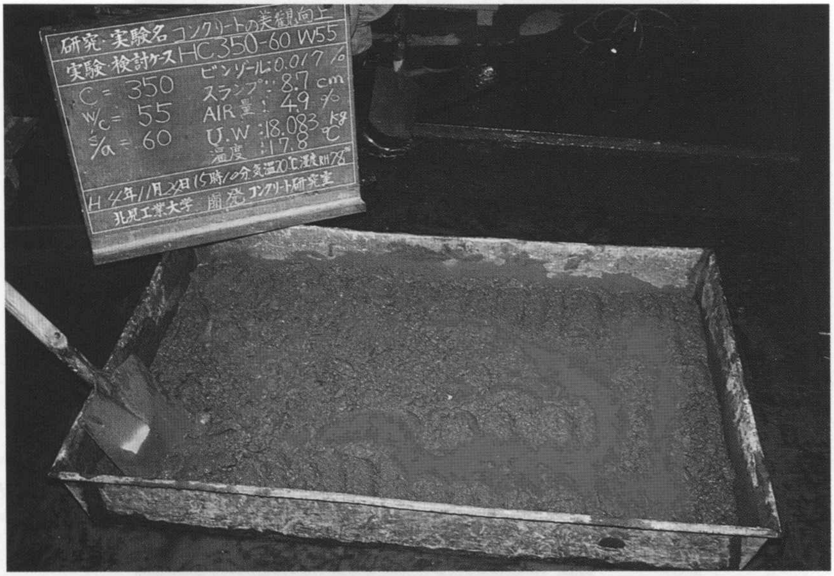

Photo 1 Fresh concrete before adding color admixture

Photo 2 Fresh concrete after adding color admixture

efflorescence-affected area was measured on each face of the specimens, and the ratio of efflorescence-affected area was found by dividing the total efflorescence-affected area by the total surface area of the specimen. The results of these observations were arranged and analyzed according to unit cement weight, curing conditions, water-cement ratio and other factors.

Photo 3 Snap of colored concrete placing

Table 2. 2 Mix proportion, nature and strength of the concrete

Specimen	Unit content (specified mix)							Property of fresh concrete and 28 day's compressive strength				
Case	water cement ratio W/C	sand percentage (%) S/a	water (kg/m³)	unit cement weight (kg/m³)	fine aggregate (kg/m³)	coarse aggregate (kg/m³)	air entrained agent *1 (%)	air content (%)	slump (cm)	final temperature of concrete mixture (℃)	28 day's compressive strength (kg/m²)	91 day's compressive strength (kg/m²)
1	40	30	100	250	613	1440	0.006	*3	0.1	21.0	316	245
2	55	30	138	250	584	1374	0.019	4.2	1.1	21.0	336	216
3	70	55	175	250	923	931	0.010	5.6	6.6	20.0	212	163
4	40	30	140	350	555	1311	0.088	3.8	1.0	16.5	322	284
5	55	60	193	350	1028	693	0.042	4.8	8.6	16.0	319	251
6	70	70	245	350	1102	479	0.053	4.6	24.1	15.0	201	171
7	40	60	180	450	784	891	0.144	5.2	8.0	16.5	360	288
8	55	47	248	450	892	602	0.324	5.3	24.4	16.3	285	219
9	70	70	315	450	918	396	0.302	4.4	*2	15.0	212	188

* 1 Weight percentage of air entraining agent to cement weight.

* 2 Measurement is impossible because over slump.

* 3 Air content of administration is impossible because stiff consistency concrete.

Table. 2. 3 The moisture and dry coefficient

Environmental condition	M
In the water	0.8
Humidity 90%	1.3
Humidity 70%	2.0
Humidity 40%	3.0

M : dry creep coefficient

Table 2. 4 Curing condition.

Curing way	Curing condition	Sign	CM
STANDARD CURING	In the water	S	125
CURING ROOM	Temperature 20°C Humidity 85%	C. R.	67
DRY ROOM	Temperature 45°C Humidity 10%	D	25
SPECIAL CURING ROOM	Temperature 20°C Humidity 95% Kept blowing CO_2 always.	S. C. (A)	94

CM··· Coefficient of moisture
The value is estimated by dry coefficient and movement of water relation to environmental condition.

3. RESULT OF OBSERVATIONS AND DISCUSSION

3.1 RESULTS

The relationship between curing conditions and the ratio of efflorescence-affected area is shown in Fig. 3. 1. 1. The actual efflorescence observed with each curing conditions is shown in Photo 4. The ratio of efflorescence-affected area in a dry curing room was the highest of all, followed by the curing room, the special curing room, and standard curing in that order. The relationship between coefficient of moisture and ratio of efflorescence-affected area is shown in Fig. 3. 1. 2. With increasing coefficient of moisture, the ratio of efflorescence-affected area fell. The relationship between water-cement ratio and ratio of efflorescence-affected area is shown in Fig. 3. 1. 3. With increasing water-cement ratio, the ratio of efflorescence-affected area increased linearly. The relationship between unit cement weight and ratio of efflorescence-affected area is shown in Fig. 3. 1. 4.

Unit cement weight has little influence on the ratio of efflorescence-affected area. The relationship between changes in the surface moisture ratio and the ratio of efflorescence-affected area is shown in Fig. 3. 1. 5. The relationship between surface moisture and the ratio of efflorescence-affected area shows a slight positive correlation, but the points are

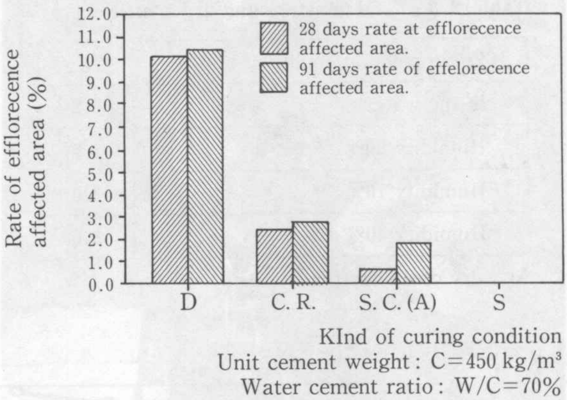

Fig. 3. 1. 1 The relationship between curing conditions and ratio of efflorescence affected area.

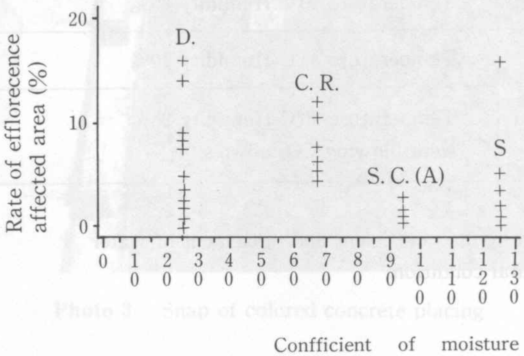

Fig. 3. 1. 2 The relationship between cofficient of moisture and ratio of efflorescence affected area.

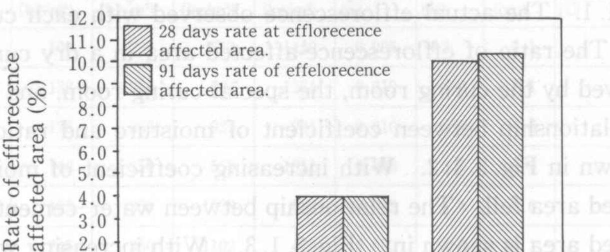

Fig. 3. 1. 3 The relationship between water-cement ratio and ratio of efflorescence affected area.

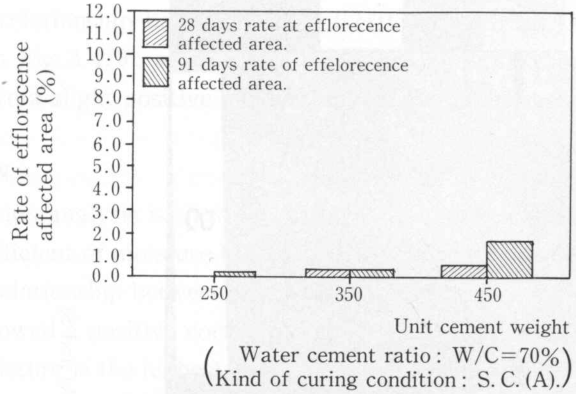

Fig. 3. 1. 4 The relationship between unit cement weight and ratio of efflorescence affected area.

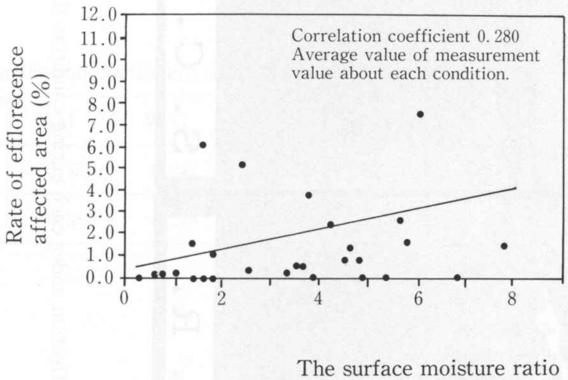

Fig. 3. 1. 5 The relationship between the surface moisture rate anol raito of efflorescence affeated area (28 days)

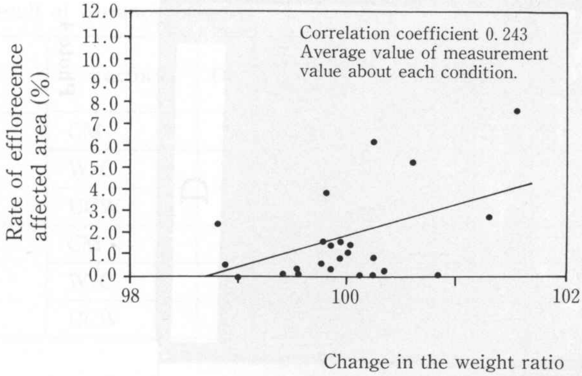

Fig. 3. 1. 6 The relationship with changes in the weight ratio (28 days'／1 days' ×100 (%))

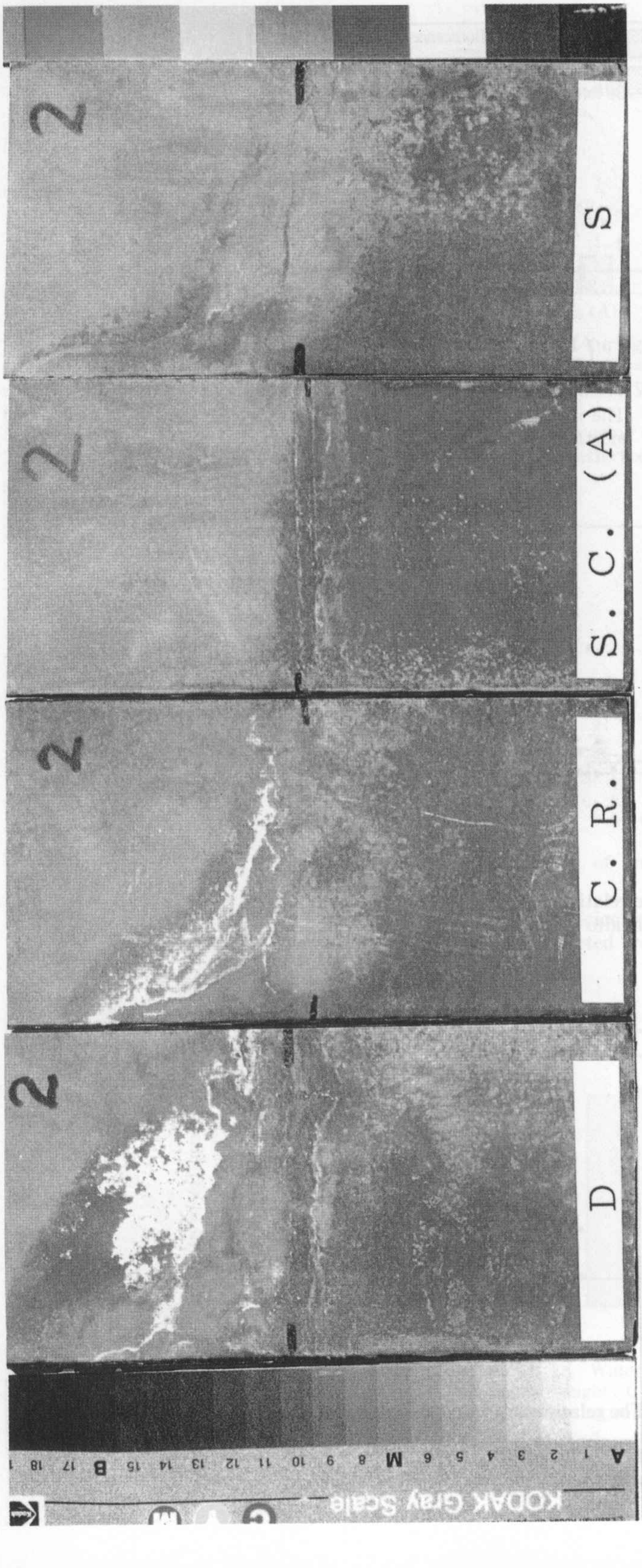

Photo 4 Efflorescence affection under each curing condition (D, C. R., S. C. (A) and S)

scattered. The relationship between ratio of efflorescence affected-area and the weight ratio is shown in Fig. 3. 1. 6 ; as in Fig. 3. 1. 5, the weight ratio and rate of efflorescence-affected area have a slight positive correlation, but the points are scattered.

3.2 DISCUSSION

The correlation analysis is shown in Table 3. 2. 1. The ratio of efflorescence-affected area and the coefficient of moisture have a negative correlation at both 28 days and 91 days. Conversely, the relationship between the ratio of efflorescence-affected area and the water -cement ratio showed a positive correlation at both 28 days and 91 days. The correlation coefficient of moisture is the highest of the correlation coefficients analyzed ; next is water -cement ratio and then unit cement weight. The results of multiple linear regression analysis are shown in Table 3. 2. 3.

Table 3. 2. 1 The correlation coefficient of analysis.

	UCW	CM	W/C	REAA 28	REAA 91	28 DCSMR	91 DCSMR	28 DCWR	91 DCWR
28 DRECA	0.023	−0.357	0.242	1.000	0.984	0.280	0.158	0.244	0.065
91 DRECA	−0.034	−0.387	0.228	0.984	1.000	0.339	0.222	0.267	0.120

REAA 28 ············Rate of efflorescence affected area at 28 days.
REAA 91 ············Rate of efflorescence affected area at 91 days.
UCW ··················Unit cement weight.
CM ····················Coefficient of moisture.
W/C ··················Water cement ratio.
28 DCSMR ·········28 days change in the surface moisture ratio.
91 DCSMR ·········91 days change in the surface moisture ratio.
28 DCWR ············28 days change in the weight ratio.
91 DCWR ············91 days change in the weight ratio.

Table 3. 2. 2 The result of variance analysis.

Analysis of variance item	Factor	DF	Sum of sguares	F-Value	PR : >F	Decision
The rate of efflorecence affected area at the 28 days	CM	3	220.459	8.20	0.0001	* *
	W/C	2	81.715	4.56	0.0127	*
	UCW	2	35.422	1.98	0.1439	
The rate of efflorecence affected area at the 91 days	CM	3	263.955	9.20	0.0001	* *
	W/C	2	90.928	4.75	0.0107	*
	UCW	2	22.426	1.17	0.3138	

The model was given in the result of multiple linear regression analysis, as follows :

$$REAA91 = 0.1839\,W/C - 0.0623CM - 1\,747 \quad \cdots\cdots\cdots\cdots \text{Equation (3.2.1)}$$

where, *REAA*91 : the rate of efflorescence-affected area at the age of 91 days
W/C : water-cement ratio
CM : coefficient of moisture

The relationship between the measurement of the ratio of efflorescence-affected area at the age 91 days and the estimate is shown in Fig. 3. 2. 1. It is likely that the ratio of efflorescence-affected area can be predicted by the model, because the significance level was within 1 %.

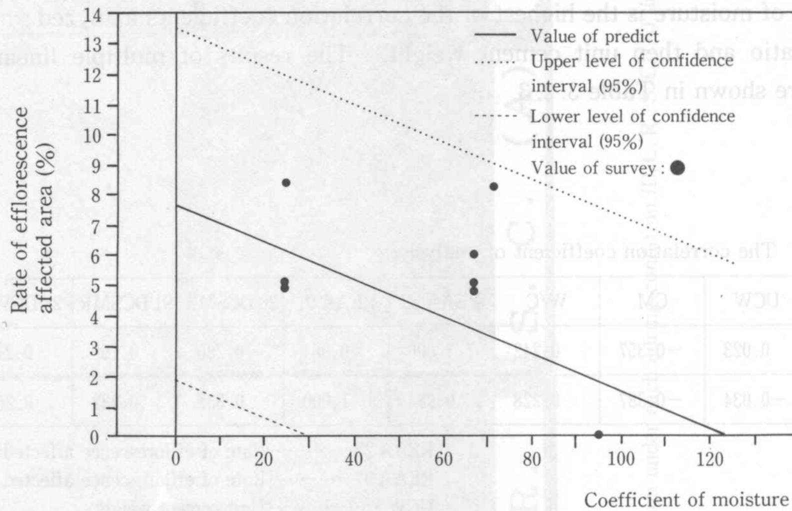

Fig. 3. 2. 1 The relationship between measurement of ratio of efflorescence at age 91 days and the estimate

4. CONCLUSION

The following results were obtained in analyzing the factors affecting the ratio of efflorescence-affected area on a concrete surface in the study on preventing efflorescence to improve beauty of concrete :

1) The coefficient of moisture has a great influence on the ratio of efflorescence-affected area, and shows negative correlation on it.
2) Water cement ratio has an influence on the ratio of efflorescence-affected area, and this relationship is positively correlated.

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