CARBONATION RESISTANCE OF CONCRETE WITH XYPEX CONCENTRATE

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1. INTRODUCTION

This research program was undertaken at Construction and Maintenance Technology Research Center (CONTEC), Sirindhorn International Institute of Technology (SIIT) of the Thammasat University with research fund from Xypex Marketing Service (Thailand). The main objective of this research was to determine the carbonation resistance of concrete which were designed to have different water to binder ratios (0.4, 0.5, and 0.6) and fly ash contents (0, 30%) with and without CCM coating were tested under an accelerated environment. The carbonation resistance of concrete can be improved by Xypex Concentrate. The carbonation depths of specimens coated with Xypex Concentrate were lower than those of the uncoated specimens of the same mix proportion.

2. MATERIALS AND MIX PROPORTIONS

Ordinary Portland cement type I (OPC I), fly ash (FA) and Xypex Concentrate (CCM) were used. Crushed limestone with specific gravity of 2.70 (G_{max} = 20 mm) and river sand with specific gravity of 2.6 (F.M. = 2.13) were used as coarse and fine aggregate, respectively. Both aggregates complied with ASTM C33 [1]. The sand to total aggregate (s/a) ratio and void ratio were 0.42 and 0.245 for all mix proportions of concrete.

Both cement-only concrete (C100) and fly ash concrete with 30% replacement (C70FA30) with different water-to-binder ratios (0.4, 0.5, and 0.6) were used in carbonation resistance test. Amount of cement paste in all concretes was controlled at 29.4% of total volume. The mix proportions are shown in Table 1.

Table 1: Mix proportions of concretes

Mix	C	FA	W	S	G
0.4	396	0	158	786	1106
0.4FA30	260	111	148	786	1106
0.5	347	0	174	786	1106
0.5FA30	230	98	164	786	1106
0.6	310	0	186	786	1106
0.6FA30	206	88	177	786	1106

Where C, FA, W, S, and G are amount of cement, fly ash, water, sand, and gravel (kg/m^3)

3. TESTING METHOD

3.1 Specimen preparation

Concrete specimens with the size of 100x100x100 mm were cast and demolded at 24 hrs after casting. These specimens were separated into 3 sets. The 1st set was for uncoated specimens (-N). The 2nd set was for specimens coated with CCM before exposure to CO_2 (-C). This set represents the case that coating is applied to the new structure that has not yet been exposed to carbon dioxide. And, the 3rd set was for specimens coated with CCM after 28-day carbonation in accelerated carbonation chamber (-E28C). This set represents the case that CCM is applied to the structure that has been already carbonated.

For coated specimens, coating process started from making the specimens into saturated surface dry condition (SSD). Then, the surfaces of specimen were cleaned by brass brush. The coating of approximately 1.25 mm thickness was subsequently applied on the surface.

3.2 Accelerated carbonation test of concrete

The accelerated carbonation test was employed to assess the carbonation resistance of concrete. The temperature and relative humidity in the carbonation chamber were controlled at 40 °C and 55%, respectively. The CO_2 concentration was 4%.The average depths of carbonation were measured at 28, 56, 77 and 91 days (4, 8, 11, 13 weeks) after the exposure (from the age of 7 days). The specimens were split, then the depths of carbonation were determined by spraying a solution of 1% phenolphthalein in 70% ethyl alcohol on a freshly broken concrete surface [2, 3].

4. RESULTS AND DISCUSSIONS

4.1 Carbonation depth of specimens coated before exposure

Figure 1 and Figure 2 show the carbonation depth of the specimens with and without CCM before CO_2 exposure (Group C specimens). Note that the carbonation depth excludes the thickness of CCM layers. Compared to the uncoated specimen (Group N specimens) of the same mix proportion, the carbonation depths of the coated specimens were remarkably reduced. The reduction may be caused by either the carbonation resistance of the crystalline coating layer itself or the improved carbonation resistance of the base concrete or both.

It is also observable that the effect of w/b and fly ash in the concrete is similar to those of uncoated concrete. Higher w/b and presence of fly ash reduce the carbonation resistance. However, the results shows that the crystalline coating reduce more carbonation depths in the case of higher w/b [4].

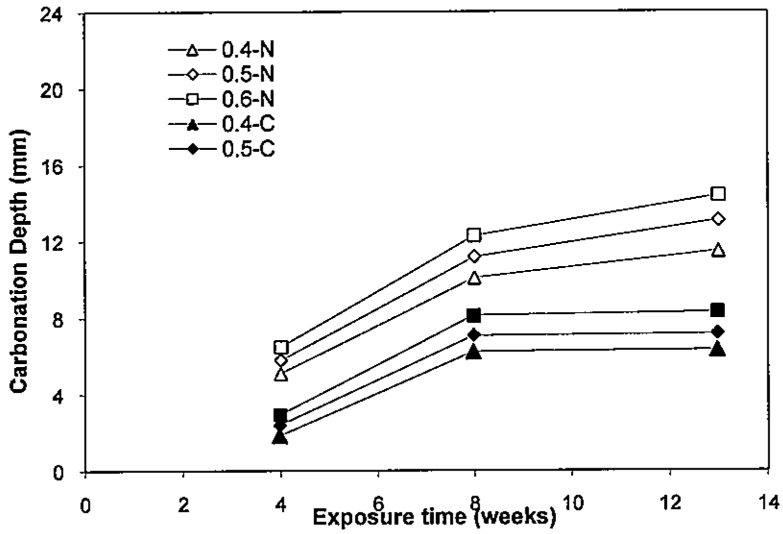

Figure 1: Carbonation depth of uncoated and coated cement-only concrete

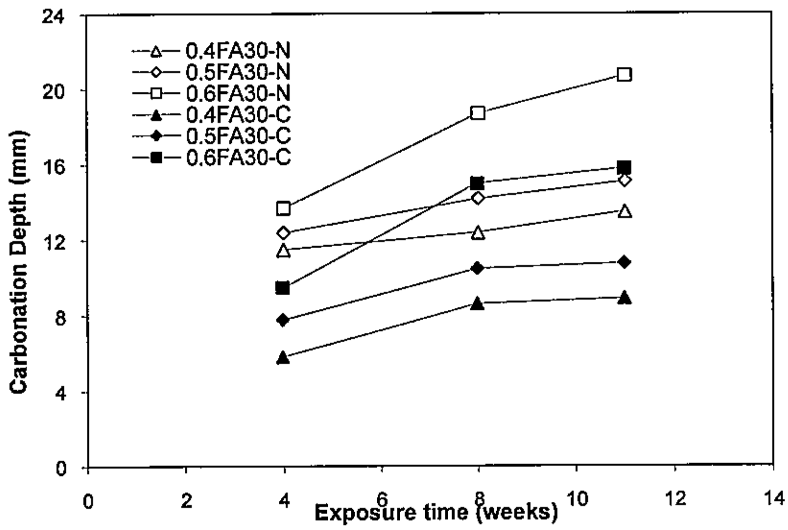

Figure 2: Carbonation depth of uncoated and coated fly ash concrete

4.2 Carbonation coefficient of specimens coated before exposure

The carbonation depths of the specimens, measured in the experiment, were used to calculate the carbonation coefficient of the concrete as shown in the following equation;

$$D_c = k_c \sqrt{t} \quad (1)$$

Where k_c is the carbonation coefficient of uncoated concrete (mm/week$^{0.5}$), D_c is the carbonation depth of concrete (mm), and t is the exposure time (weeks).

When the CCM is applied on the surface of specimens, it acts as a protective layer that retards the diffusion of CO_2 into the base concrete. The carbonation depth is thus dependent on diffusion coefficients of both the CCM and the base concrete. With the assumptions that the modified carbonation coefficient (k_{mo}) of the base concrete with CCM coating includes the effect of pore refinery at near-surface portion of the base concrete by CCM and that the carbonation coefficient of each material is uniform in its domain, the contribution of the coating layer to carbonation resistance as well as the carbonation coefficient of the base concrete after coating can be evaluated [4].

Figure 3 compares the carbonation coefficients of uncoated concrete with those of the base concrete of coated specimens (k_c and k_{mo}, respectively). The carbonation coefficient increases with the increase in fly ash content and w/b. It is obvious that the base concrete with coating have remarkably lower carbonation coefficient than the uncoated specimens [4]. The measured carbonation depth, the carbonation coefficient of uncoated concrete, and the modified coefficient of coated base concrete are given in Table 2.

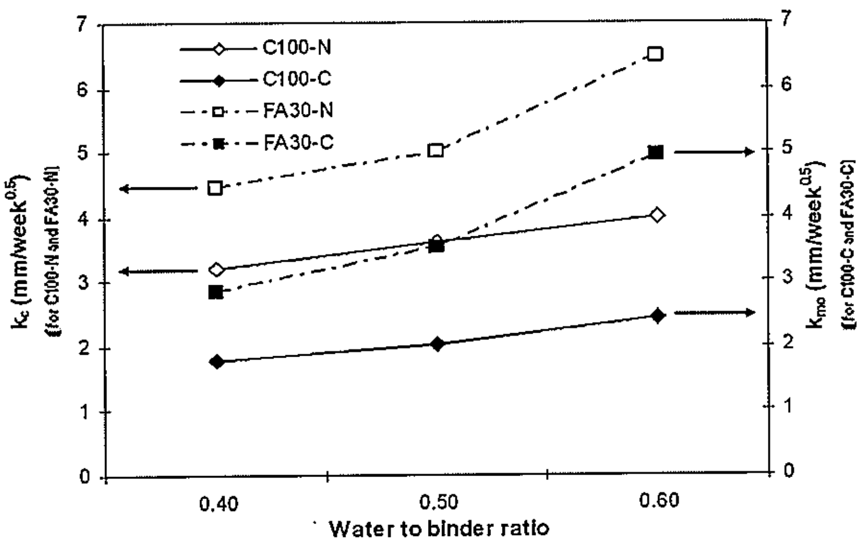

Figure 3: Carbonation coefficient of concrete

4.3 Effect of coating on carbonated concrete

Figures 4 and Figure 5 show the change of modified carbonation depth (excluding the thickness of CCM layer) of the coated base concrete specimen that was coated by CCM after being carbonated for 28-day (Group E28C). The results show that when, CCM coating was applied after concrete had been carbonated, the modified carbonation depth was reduced. The CCM coating on carbonated specimens (Group E28C) can yield outstanding short-term performance; the carbonation depth can be much reduced so that it became even lower than the carbonation depth of specimens coated before exposure (Group C) at 8 weeks. However, after 11 weeks of exposure, the specimens coated before exposure (Group C) show best carbonation resistance (lowest carbonation depth) in both the cases of cement-only concrete and fly ash concrete. This implies that CCM coating is more efficient if applied before the concrete is exposed to carbonation [4].

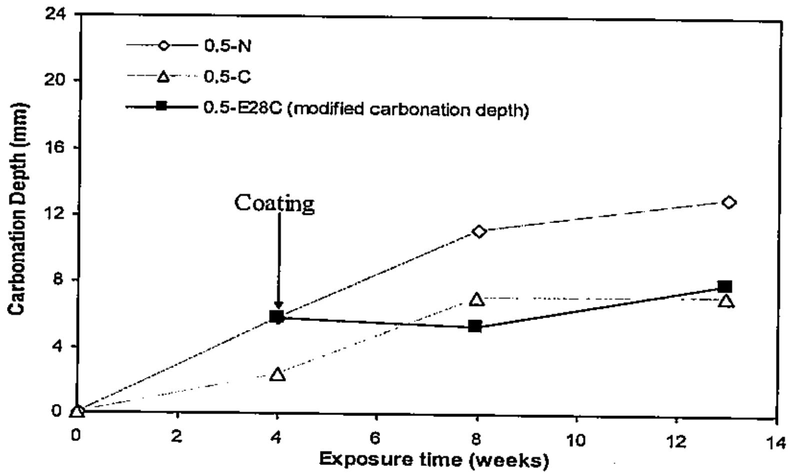

Figure 4: Carbonation depth of carbonated specimen before coating

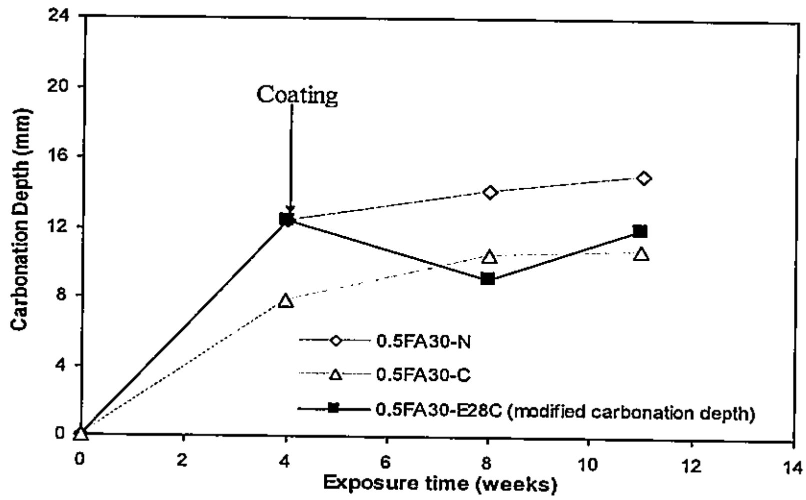

Figure 5: Carbonation depth of carbonated fly ash concrete before coating

Table 2: Carbonation depths and carbonation coefficients

Mix	D-4 (mm)	D-8 (mm)	D-11 (mm)	D-13 (mm)	k_c (mm/weeks$^{0.5}$)	k_{mo} (mm/weeks$^{0.5}$)
0.4-N	5.1	10.1	-	11.5	3.21	N/A
0.4-C	1.84	6.24	-	6.34	3.21	1.77
0.4-E28C	-	4.87	-	7.17	N/A	N/A
0.4FA30-N	11.5	12.4	13.5	-	4.47	N/A
0.4FA30-C	5.82	8.62	8.92	-	4.47	2.85
0.4FA30-E28C	-	7.03	9.43	-	N/A	N/A
0.5-N	5.8	11.2	-	13.1	3.62	N/A
0.5-C	2.40	7.10	-	7.20	3.62	2.03
0.5-E28C	-	5.37	-	7.97	N/A	N/A
0.5FA30-N	12.4	14.2	15.1	-	5.00	N/A
0.5FA30-C	7.78	10.48	10.78	-	5.00	3.53
0.5FA30-E28C	-	9.07	11.97	-	N/A	N/A
0.6-N	6.5	12.3	-	14.4	3.99	N/A
0.6-C	2.93	8.13	-	8.33	3.99	2.35
0.6-E28C	-	5.37	-	9.22	N/A	N/A
0.6FA30-N	13.7	18.7	20.7	-	6.48	N/A
0.6FA30-C	9.48	14.98	15.78	-	6.48	4.95
0.6FA30-E28C	-	13.6	16.44	-	N/A	N/A

Note: D-4, D-8, D-11, and D-13 are the carbonation depth of concrete behind the coat after carbonated for 4, 8, 11, and 13 weeks in the carbonation chamber, respectively.

5. CONCLUSION

This test results show the carbonation resistance of cement-only concrete and cement-fly ash concrete coated with Xypex Concentrate under accelerated environment. Xypex Concentrate (CCM) reduces carbonation depth approximately 35-50% and carbonation coefficient of concrete approximately 35-45% when compared to normal concrete.

6. REFERENCES

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