

EFFECT OF CARBONATION ON MICROBIAL CORROSION OF CONCRETE

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1. INTRODUCTION

The corrosion of concrete in sewage treatment plants and sewer collection systems are well-known. The collapse of concrete structures exposed to H_2S gas and subsequent biogenic sulphuric acid attack cause major economic loss and maintenance problems. Since its placement, the virgin concrete will experience various types of physical and chemical changes before deteriorating and collapsing. Despite numerous improvements in preventing corrosion to occur such as use of epoxy lining, sacrificial layers, and sulfate-resistant concrete, the structures continue to deteriorate though at slower rates.

Carbonation of concrete in sewer environment is the prerequisite for further stages to microbial corrosion. The main effect of carbonation is the reduction of pH. Eventhough carbonation by air does not exceed few millimeters, it is sufficient to permit sulfur-oxidizing bacterias to colonize and initiate microbial corrosion on the surface of concrete. In addition to reduction in pH and chemical changes in hydration products, it had been reported¹ that carbonation can stimulate the migration of corrosive factors which had been fixed in the interior even before subjected to external attack.

Carbonation of concrete to some extents has the beneficial and detrimental effects in protection against aggressive environments. In sewer pipes or treatment plants, the concentration of CO_2 gas is considerably higher than usually exist in air. D. Thistlethwayte (1972) reported that CO_2 concentrations in main sewers were around 3%. This study is carried out to determine the effect of carbonation on microbial corrosion of mortar specimens by *T.thiooxidans* species.

2. MATERIALS AND METHODS

Mortar specimens of 40 X 40 X 160 mm were prepared by mix proportion of 520g cement(OPC), 1040g standard sand, and 338g water. After one day curing at 100% RH, the specimens were demoulded and cured in water for 27 days at 20°C. Then for 3 months, the specimens were stored in humid box at 20°C. Specimens were placed in plastic chambers measuring W440 X L300 X H300 mm. For the first four months, only gas CO_2 of 5%, 0.5%, and atmospheric air(control) were introduced. The concentrations of CO_2 were adjusted by regulating the air and CO_2 flowmeters and measured by gas chromatography. During four months, carbonation depths by phenolphthalein coloration test were measured.

After four months, sewage influent was introduced and *T.thiooxidans* was inoculated weekly for one month period. In addition to CO_2 , hydrogen sulphide H_2S gas of 100ppm is also introduced and 50-70% RH is kept by use of humidifiers as shown in Figure 1. The temperature is according to room temperature. pH changes, mass losses, corrosion depths, and corrosion rates were investigated.

3. RESULTS AND DISCUSSION

Figure 2 shows the effect of four months carbonation on the thickness of carbonated layers for specimens exposed to 5%, 0.5% CO_2 , and control. After 19 days of exposure to CO_2 , the thicknesses of 5% and 0.5% specimens were 3.0mm compared to 1.7mm in control. During 4 months, carbonated layers of 5% and 0.5% specimens increased gradually and attained thicknesses of 6.5 and 8.0mm, respectively. In contrast, control specimens only achieved 3.3mm after 4 months. In case of 5% and 0.5% specimens, carbonation effect was more pronounced in the later. However, the rate of CO_2 penetration inside the mortar was the highest at 5% (at least for first 55 days). After CO_2 reacted with $\text{Ca}(\text{OH})_2$, moisture will be diffused out. If the diffusion out is slower than the CO_2 diffusion inside the mortar, further diffusion of CO_2 into the interior will be slowed or stopped. Calcite formation also caused a decreased in pore volumes and reduced the CO_2 intrusion.

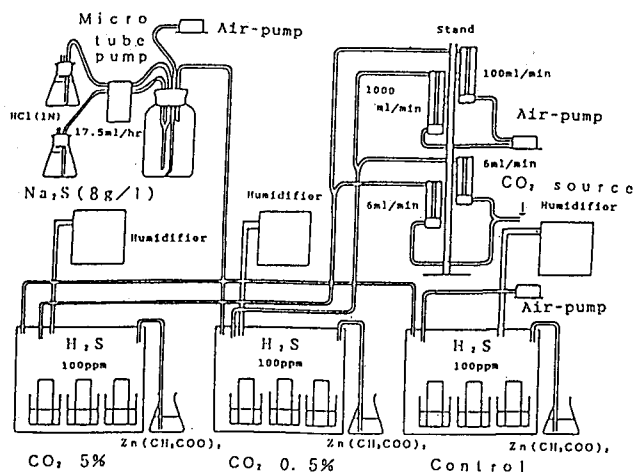


Fig. 1- Set-up of microbial corrosion and carbonation of mortar specimens experiment

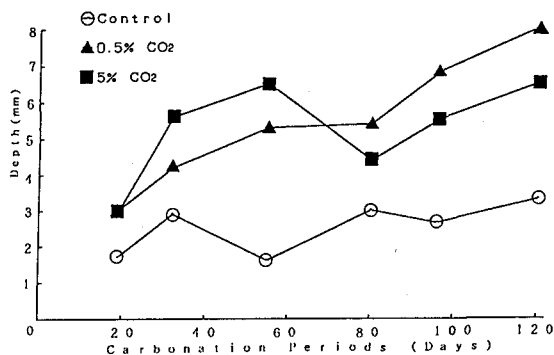


Fig. 2- The change of carbonation depth with time

The introduction of H_2S gas and *T. thiooxidans* caused a decreased in mortar surface pH as shown in Fig. 3. After 2 weeks, the pH of 5%, 0.5%, and control were 4.8, 4.0, and 5.4, respectively. Four months carbonation had reduced the surface pH which was vital for *T. thiooxidans* to colonize and proliferate. After 40 days, the pH of 5% and 0.5% specimens declined drastically from 3.9 and 4.0 to 2.2 and 2.3, respectively. Control specimens exhibited gradual decline in pH instead. It always maintained higher pH than 5% and 0.5% but after 6 months the pH were about the same in all categories. Similarly but more slowly, the middle and upper parts of mortars also exhibited same pattern of declining pH.

Results from Table 1 show the effect of carbonation on microbial corrosion of mortar specimens. After 4 months, mortar specimens exposed to 5% and 0.5% CO_2 deteriorated and had higher corrosion depths, corrosion rates, and mass losses than control. Six months later, the corrosion rates for both 5% and 0.5% specimens were about 1.5 times higher than the control. The rates of corrosion of 5% and 0.5% were about the same but slightly greater in the later. The reason may be attributed due to lesser carbonated areas and by early beneficial formation of carbonated surface layer in 5% which act as a protection layer against sulphuric acid attack. Osborne³ concluded that a carbonated outer layer in concrete was effective in prevention against sulphate attack.

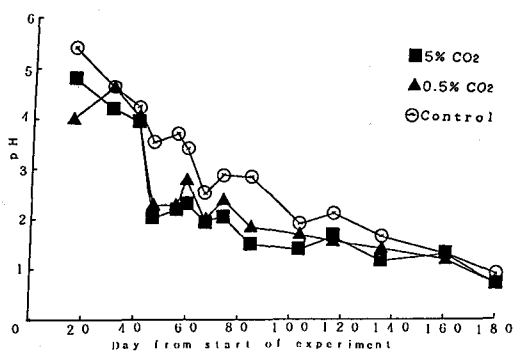


Fig. 3- Decrease in mortar surface pH in chambers receiving 100ppm H₂S and CO₂ gases

Table-1 Effect of Carbonation on Microbial Corrosion of Mortar Specimens

Specimens	Mass loss (g)		Corrosion Depth (mm)		Corrosion Rates (mm/year)	
	4months	8months	4months	8months	4months	8months
Control	16.45 (3.00%)	21.90 (4.00%)	1.35	2.43	2.00	4.90
0.5%	25.05 (4.60%)	31.10 (5.65%)	1.87	3.94	2.80	7.90
5%	19.00 (3.51%)	26.55 (4.95%)	1.75	3.53	2.62	7.10

4. CONCLUSIONS

1. After 4 months the thickness of carbonation was highest in 0.5%, followed by 5% and control.
2. Carbonated outer layer was essential for *T.thiooxidans* to colonize and proliferate and initiate microbial corrosion.
3. Carbonation accelerated the corrosion rates at early stage. Specimens exposed to 5% and 0.5% CO₂ were greatly corroded than the control and 0.5% mortar specimen was the most corroded.
4. Early formation of carbonated outer layer in 5% specimen might contribute a protective layer against sulphuric acid attack which probably explain why corrosion rate for 5% was smaller than 0.5% specimen.

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