II-447 CORROSION ON CONCRETE SEWER PIPES-THE EFFECT OF H_2S CONCENTRATION, TEMPERATURE AND INOCULATION

Ruddy Noriega°, Tonomori Matsuo° and Keisuke Hanaki°
Hiroshi Nishisawa°°, Kuniharu Yoshimoto°° and Kazuhiro Tanaka°°
° Department of Urban Engineering, The University of Tokyo.
°° Japan Sewage Works Agency, Toda Laboratory.

INTRODUCTION The internal surface of concrete sewers is frequently subject to rapid corrosion, leading in some cases to complete disintegration. This process is known as "**biogenic sulfuric acid corrosion.**" This particular form of corrosion occurs only where hydrogen sulfide (H_2S) released into the sewer atmosphere is absorbed in the condensed water on the inner sewer wall, and then microbiologically oxidized by the sulfur oxidizing bacteria of the genus ***Thiobacillus*** to sulfuric acid. Corrosion problems in Japan generally occur at pumping-main and siphon discharges where sewage has become anaerobic due to the excessive retention time in the pressured lines and sumps. Also in sewage treatment plants, particularly at the sludge thickeners, secondary flow recycling lines, and at night soil receiving tanks, where H_2S concentration varies from hundreds to thousand ppm's.

The purposes of the present study were to determine the corrosion rate of concrete samples placed in chambers to which various concentrations of H_2S were continuously supplied at two different temperatures simulating seasonal conditions. The performance of four coating materials commonly used in sewage works also was evaluated.

EXPERIMENTS The experiments were carried out in 5 (150l) chambers made of transparent PVC. Figure 1 shows a schematic section of the simulation chambers. The samples exposed to the corrosive atmospheres were centrifugally spun concrete Hume pipe segments (Ø 200mm), which were cut in circular sections (Fig. 2) and cubes. The inoculation of the samples was done by submersion into a tank filled with ***Thiobacillus*** stock culture. Each reactor was divided in three areas for inoculated, non inoculated, and inoculated coated samples. Inoculated samples were monthly reinoculated. The coating materials tested were: vinylester, polyester, tar-epoxy, and polyurethane; the thicknesses of the coating were among 2 to 3 mm. The chambers' atmospheres were adjusted for the conditions shown in Table 1. The corrosion rate on the concrete samples were studied by removing pipe samples and cubes from each reactor every two month. Samples after the exposure period were brushed, dried, weighted, and measured their thickness at controlled points (every 22.5°). In case of cube samples the corrosion was evaluated as loss of mass. The corrosion process was closely followed up by a weekly monitoring of the condensed water recovery from each sample. The parameters controlled were: total sulfur, sulfates, total calcium, total silica, total aluminum, acidity, pH, conductivity, and hydrogen sulfide.

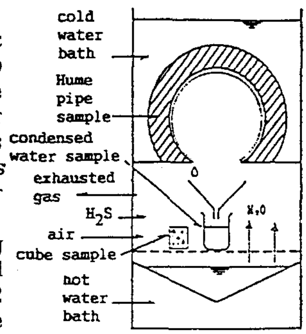

FIGURE 1

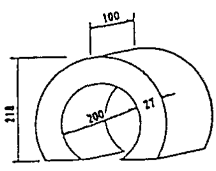

FIGURE 2

RESULTS AND DISCUSSION The formation of sulfuric acid on concrete surfaces exposed to atmospheres containing H_2S is a chemical and mainly biological process. It depends of several environmental factors such as: moisture, temperature, concentration of hydrogen sulfide, nutrients and the concentration of the sulfur oxidizing bacteria "***Thiobacillus***" among others. During the experiment, samples inoculated with ***Thiobacillus*** stock culture shown a faster decrease of the pH on the concrete surface, as well as higher sulfate concentration and acidity in condensed water than no inoculated samples. The corrosion rate on a concrete pipe for a given H_2S concentration, shown an initial lag period where inoculated and non inoculated samples had the same corrosion rate. Inoculated samples shown a decreasing bacterial activity due to the

the material and the trace nutrients'limitation, the effect of reinoculation on the samples has seems to be very important for the enhancement of corrosion. As soon as the acidophilic Thiobacilli become well established a rapid increase in the corrosion rate was observed (Fig. 3).

Temperature is a very important factor in the biogenic corrosion process of the concrete, since the optimum temperature for the growth of ***Thiobacillus*** is 28° to 30°C. Pipe samples inoculated and exposed to an atmosphere containing 800 ppm of H_2S at 25°C (R4) showed approximately 30% more corrosion than samples exposed to the same conditions at 10°C (R5) as shown in figure 4. In case of concrete cubes the loss of weight for samples at 25°C (R4) was double than the loss of weight observed in samples at 10°C (R5) (Fig. 5).

The effect of hydrogen sulfide concentration ($[H_2S]_g$) on the corrosion process during the first stage of this experiment (first 170 days) seems insignificant. There is not a clear relation between H_2S concentration and the corrosion rate on pipe samples or the loss of weight in cube samples. However the effect of $[H_2S]$ on the analytical parameters such as acidity, pH, total sulfur and sulfate was observed in the inoculated samples. The corrosion of centrifugally spun concrete pipe is initially a slow process as long as the inner face is almost a neat cement layer, the high alkalinity of this layer retards or impedes the progress of the sulfuric acid attack. Alkalinity of the interior wall of concrete pipe varies with the manufacturing method. Table 2 shows a comparison between the corrosion rate on centrifuged concrete and melted concrete samples for the same concrete constituent.

Samples coated with tar-epoxy and polyurethane has shown spot blistering after having been exposed for 67 days to atmospheres of 200 and 800 ppm of H_2S, also in samples coated with polyester blisters were observed after 152 days. A section cut around a bubble under the Tar-Epoxy sample, showed a failure of adherence between the coating (base mat) and the concrete surface. The failure of the coating during the experiment is perhaps due to the H_2S gas; which may penetrate the coating barrier and builds up a pressure inside and causing a bond failure. Blistered areas are affected by tractive forces, which develops microscopical cracks leading the H_2SO_4 penetration of the coating and finally the attack of the concrete surface. A microscopic observation of the coated surface permitted to find many pin holes of 0.25-0.5 mm diameter.

TABLE 1. ENVIRONMENTAL CONDITIONS IN THE CHAMBERS

REACTOR	1	2	3	4	5
TEMPERATURE (°C)	25°	10°	25°	25°	10°
$[H_2S]_{(g)}$ (ppm)	50	50	200	800	800

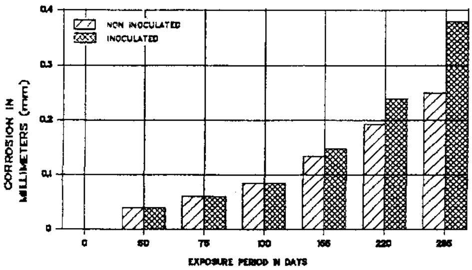

FIG. 3 THE EFFECT OF INOCULATION ON PIPE SAMPLES AT $[H_2S]$:50 ppm

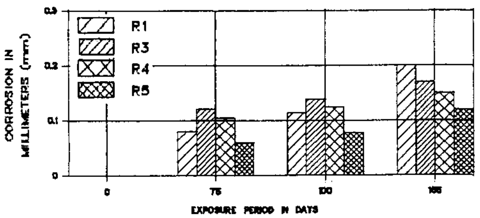

FIG. 4 CORROSION ON INOCULATED PIPE SAMPLES

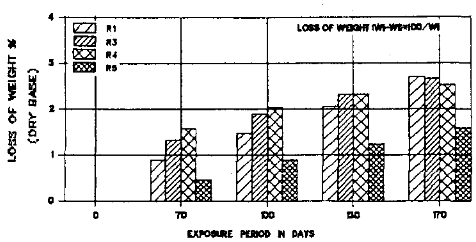

FIG. 5 CORROSION ON INOCULATED CUBE SAMPLES

TABLE 2. CORROSION RATE ON CONCRETE SAMPLES

SAMPLE	[H2S]g ppm	EXPOSURE PERIOD DAYS	LOSS OF THICKNESS AVG mm	MAX mm
MELTED IN MOLD	400 1000	105 135	0.52 0.84	1.1 -
CENTRIF SPUN	50 200 800	135 135 135	0.12 0.07 0.09	0.16 0.16 0.14