ABSTRACT

Ding, Ling. M.S., Purdue University, December 2015. Assessing The Performance of Antimicrobial Concrete Admixtures in Concrete Subjected to Microbially Induced Corrosion. Major Professor: Ernest R. Blatchley III.

Concrete is the mostly widely used material in wastewater storage, conveyance, and treatment. The hydrated Portland cement in concrete makes it susceptible to degradation under highly acidic conditions. The process known as microbially induced corrosion (MIC) can promote concrete deterioration and incur large maintenance costs. MIC is caused by the metabolic products of two groups of microorganisms. Anaerobic bacterial activity below the water line results in the production of aqueous hydrogen sulfide (H_2S). H_2S then escapes into the gas phase and is oxidized to sulfuric acid by aerobic bacteria residing on concrete surfaces above the water line. This results in sulfuric acid attack of Portland cement by dissolution of calcium hydroxide and formation of corrosion byproducts, including gypsum and ettringite. The attack gradually moves from the outer surface to the core of the concrete, causing coarse aggregate to be dislodged, reducing wall thickness and destroying structural integrity, and in some case exposing structures to wastewater.

Several challenges have been associated with assessment of MIC. First, no standard method has been developed to assess concrete susceptibility to MIC; reproduction of MIC in a laboratory setting is limited by the need to culture specific bacterial strains

and by handling of H_2S. In-situ experiments are helpful for quantification of the effects of MIC in the field; however, the best locations for sample placement are not clearly defined, and the results are influenced by a number of factors that cannot be controlled in field experiments. In natural systems, concrete deterioration can also be influenced by other factors, including bacteria remaining on the cylinders.

A combination of laboratory and field experiments was conducted to quantify the effects of MIC on a range of concrete mixtures, some of which included an antimicrobial agent designed to inactivate the bacteria that promote the process. The laboratory experiments were conducted in an isolated chamber wherein climate was controlled, including gas-phase H_2S concentration. Concrete specimens representing 13 mixtures were inoculated with four species Thiobacillus bacteria (Thiobacillus thiooxidans (ATCC® 8085), Thiobacillus neapolitanus (ATCC®23641), Thiobacillus thioparus (ATCC®8185) and Thiomonas intermedia (ATCC® 15466). Results indicated that CAC (calcium aluminate cement) mortar, Australian cement, and incorporation of an antimicrobial agent can improve resistance to MIC under moderate MIC conditions (i.e., surface pH>2.0). Rapid deterioration of specimens exposed to more aggressive conditions in the chamber indicated that degradation of concrete under the most severe MIC conditions (i.e., concrete surface pH<2.0) cannot be prevented by manipulating concrete mixture proportions.

The second experiment involved a field test designed to evaluate the resistance of 13 concrete mixture designs to H_2S exposure of three locations within a municipal wastewater collection system. It was found that exposing to lower H_2S $_{(g)}$ concentration can increase concrete resistance to MIC compared to higher H_2S $_{(g)}$ concentration. However, the length of exposure was not sufficient to make clear distinctions between the performances of different mixture designs.

The third set of experiments involved a test to quantify the effectiveness of the antimicrobial agent for inactivation of pure cultures of planktonic bacteria. Results indicated that the antimicrobial agent performed well for inactivation of pure cultures of Thiobacillus bacteria, except for Thiobacllus thiooxidans under the most severe condition (i.e., a solution pH<2).