ABSTRACT

House, Mitchell W., M.S.C.E., Purdue University, August 2013. Using Biological and Physico-Chemical Test Methods to Assess the Role of Concrete Mixture Design in Resistance to Microbially Induced Corrosion. Major Professor: Jason Weiss.

Concrete is the most widely used material for construction of wastewater collection, storage, and treatment infrastructure. The chemical and physical characteristics of hydrated portland cement make it susceptible to degradation under highly acidic conditions. As a result, some concrete wastewater infrastructure may be susceptible to a multi-stage degradation process known as microbially induced corrosion, or MIC. MIC begins with the production of aqueous hydrogen sulfide ($H_2S_{(aq)}$) by anaerobic sulfate reducing bacteria present below the waterline. $H_2S_{(aq)}$ partitions to the gas phase where it is oxidized to sulfuric acid by the aerobic sulfur oxidizing bacteria *Thiobacillus* that resides on concrete surfaces above the waterline. Sulfuric acid then attacks the cement paste portion of the concrete matrix through decalcification of calcium hydroxide and calcium silica hydrate coupled with the formation of expansive corrosion products. The attack proceeds inward resulting in reduced service life and potential failure of the concrete structure.

There are several challenges associated with assessing a concrete's susceptibility to MIC. First, no standard laboratory tests exist to assess concrete resistance to MIC. Straightforward reproduction of MIC in the laboratory is complicated by the use of microorganisms and hydrogen sulfide gas. Physico-chemical tests simulating MIC by immersing concrete specimens in sulfuric acid offer a convenient alternative, but do not accurately capture the damage mechanisms associated with biological corrosion. Comparison of results between research studies is difficult

due to discrepancies that can arise in experimental methods even if current ASTM standards are followed. This thesis presents two experimental methods to evaluate concrete resistance to MIC: one biological and one physico-chemical. Efforts are made to address the critical aspects of each testing method currently absent in the literature.

The first method presented is a new test to evaluate performance of concrete specimens under conditions designed to accelerate MIC. Concrete specimens representing 12 mixture designs were inoculated with 5 species of *Thiobacillus* bacteria and placed in a biological growth chamber designed to encourage bacterial growth and sulfuric acid production by optimizing temperature, delivering necessary nutrients, and providing hydrogen sulfide gas. Results indicate that using supplementary cementitious materials, limestone aggregates, and sulfate resistant cement can improve resistance to MIC. It is interesting to note that this study showed that unlike many other durability problems the role of w/c was unclear.

The second method presented is a sulfuric acid immersion study designed to evaluate the resistance of 12 concrete mixture designs to 5 concentrations of sulfuric acid. Experimental protocols (like those in ASTM) previously considered trivial were found to have a dramatic effect on experimental results. It was found that using supplementary cementitious materials, limestone coarse aggregate, and sulfate resistant cement can increase concrete resistance to moderate sulfuric acid concentrations. The primary damage mechanism was observed to change depending on sulfuric acid concentration. Rapid deterioration of specimens exposed to aggressive sulfuric acid solutions indicates that degradation of concrete under the most severe MIC conditions (i.e., a $pH < 1.0$) cannot be prevented by strictly manipulating concrete mixture proportions. A holistic approach is needed for these situations that considers environmental conditions as well.