A Test Program to Study the Effectiveness of Coating Systems to Inhibit Corrosion in Concrete and Clay Brick Structures

Mangesh K. Kanaskar And C. Vipulanandan
Department of Civil and Environmental Engineering
University of Houston, Houston TX 77204-4791
Phone: 713-743-4291 E-mail: mkanaska@bayou.uh.edu

Abstract

Biogenic corrosion of concrete sewer pipe, wastewater collection systems and treatment plants has been reported from many parts of the world. The primary objective of this research is to study the deterioration of concrete and clay brick under the attack of sulfate ions and to determine a suitable criterion which can be used to quantify the deterioration of concrete and clay brick. To achieve this, 3" X 6" concrete cylinders and 2"X1.75"X8" clay bricks (wet and dry) were immersed into three solutions, deionized water, 3% sulfuric acid and 30% sulfuric acid. Half of the acid solution specimens were immersed halfway in the solutions while the other half were immersed fully into the solution. Specimen weight, diameters in six different directions and pulse velocities of the specimen were recorded before their immersion. The initial pH and calcium ion concentration for each solution were also recorded. These parameters were also measured at regular intervals of time along with the calcium ion concentration and pH of the solutions. Concrete and clay brick specimens were coated and also investigated in the above study. Intentional holidays were made into these specimens to study facilitated penetration of sulfate ions. Bonding of the coating material to the concrete/clay brick substrates was investigated.

1. Introduction

Concrete is the most widely used construction material in wastewater collection and treatment systems. Concrete corrosion takes place because of the biochemical transformations that take place on inorganic sulfur which is almost always invariably present in the sewage. Sulfur reducing bacteria (SRB) reduce the sulfide and produce hydrogen sulfide, H2S, gas which reaches the crown of the sewer pipe. At the pipe crown, it is oxidized to sulfuric acid by the Thiobacillus species which are sulfur oxidizing bacteria. This sulfuric acid produced reacts with the cement binder in concrete to form expansive end products causing concrete to lose its strength properties. This problem occurs predominantly in areas of pipes where temperatures are high and flow is slow. The older the pipe is, the surer it is to have corrosion. There are pipes in this country which have been carrying sewage for more than 50 years. A few sanitary sewers in New York and New Jersey have been in use since 1840's.

All the above clearly warrant an in-depth study of the concrete corrosion due to attack of sulfate ions. A proper understanding of the factors that play a major role in corrosion of concrete and quantification of the same will go a long way in understanding and solving the corrosion problem.

2. Testing Program

Tests to study the corrosion of concrete and clay brick specimens and the bonding of the coating to the substrate were carried out. For chemical resistance, modified ASTM G-20 was done on 3"X 6" concrete cylinders and 2"X1.75"X8" clay bricks. In case of the coated specimens, intentional holidays of three different sizes, 1/2", 1/4" and 1/8" were made in the specimens. Both dry and wet specimens were investigated. Solution and specimen characteristics like pH, calcium concentration, specimen dimensions and pulse velocity were measured at regular time intervals. For the coated specimens, tests were also done to study the bonding of the coating material to the substrate. The two types of tests done were ASTM C-321 and ASTM D-4541. In both the tests, the parameter measured was the load required to fail the bonding or the coating or the substrate.

3. Results and Discussion

3.1 Chemical Tests

The attack of sulfuric acid on concrete specimens is very fast. Average weight increase within first few days was around 3 to 4%. In case of 30% acid solution, the concrete specimens failed completely within one month. The 3% acid specimens showed signs of surface corrosion (the underlying coarse aggregate became visible) after first few days. In case of deionized water, the pH became very alkaline within 24 hours of immersion and weight also increased. In the case of clay bricks, no corrosion was observed as such, even in case of 30% acid solution. In the case of the coated specimens also, weight and calcium ion concentrations were observed to increase with time. Some of the coating systems being investigated failed in the 1/2" holiday specimens in 30% acid solution.

3.2 Bonding Tests

A total of 162 tests were performed on concrete and clay brick substrates. On an overall basis, the percentage of failures in Type 1 mode (substrate failure) was 45% and the percentage of failures in Type 3 mode (bonding failure) was 31%. For concrete substrate alone, the percentage of failures in Type 1 mode was 37% while that of failures in Type 3 mode was 31%. The corresponding figures for clay brick substrate were 48% and 30% respectively. This shows that bonding of coatings to both concrete and clay brick is generally satisfactory. Generally, coatings investigated were found to bond better to wet substrate than dry substrate.

4. CONCLUSIONS

Almost all the coating systems, with concrete, showed either blistering or complete failure in 30% acid solution. The time required for blistering or failure was dependent on the coating. After four to five weeks of immersion, specimens immersed in 3% acid solution showed either surface corrosion or change in the color of the coating. Deionized water did not seem to have any effect on the specimens whatsoever though the pH became very alkaline in case of pure concrete specimens.

Bonding tests showed that while some coating systems had excellent bonding with the substrate, others bonded very poorly. Bonding of coatings to substrates was found to be generally satisfactory based on the relative percentage of failures in Type 1 and Type 3 modes.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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University of Houston, Department of Civil and Environmental Engineering4800 Calhoun, Houston, TX 77024
Phone 713-743-4278 Fax 743-4260