Florida Atlantic University

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Next Generation of Epoxy Cured Cements Outperform Older Technologies

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FAU
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Acid Environment - Wastewater

Most of the world's wastewater infrastructure is constructed using concrete, one of the most versatile materials available. Concrete is strong, formable, fairly inexpensive, and has a relatively good lifespan. However, it also has some limitations. It is not ideally suited for longevity in the corrosive environments found in a typical wastewater infrastructure because wastewater environments contain sulfuric acid, which attacks concrete in these wastewater environments.

The effect of sulfuric acid on concrete and steel surfaces in these environments poses a serious challenge to the longevity of this infrastructure and, as a result, to our economy.

In the U.S. alone, corrosion causes sewer infrastructure losses that are estimated, conservatively, to be around $14 billion per year.

The formation of Sulfuric Acid (H_2SO_4)

H_2SO_4 forms through a bacterially mediated process called "biogenic sulfide corrosion."

Sewage, which contains proteins that include organic sulfur compounds, enters a wastewater collection system. Oxygen present (dissolved in the water) is reduced as bacteria begins to catabolize this organic material.

Chemical Representation

Organic bacteria + SO_4^{-2} => S^{-2} + H_2O + CO_2
$S^{-2} + 2H^+ => H_2S$
H_2S (g) + $2O_2$ (g) => H_2SO_4 (l)

- In the absence of dissolved oxygen and nitrates, sulfates are reduced to hydrogen sulfide.
- Hydrogen sulfide gas is biochemically oxidized in the presence of moisture to form sulfuric acid.

Corrosion

Sulfuric acid produced by microorganisms (as described above) will interact with the surface of the concrete substrate. Sulfuric acid reacts with the calcium hydroxide in concrete (Portland cement) to form calcium sulfate. See the chemical reaction below:

H_2SO_4 + Ca (OH)2 => $CaSO_4$ + 2 H_2O

Concrete is harmed by this acid attack, because the acid affects its natural alkaline nature. The alkaline components of cement paste (calcium hydroxide) break down with acid exposure.

Prevention of Corrosion in Concrete

Traditionally, corrosion of concrete has been prevented by using some kind of a barrier material. These materials are resistant to biogenic corrosion. They typically include epoxies and urethanes.

These are not perfect materials, but have two simple advantages:

- They are not as porous as concrete.
- They are much more resistant to highly acidic environments.

Current Cementitious Materials and Their Uses
Cementitious materials can typically be classified as:

1. Traditional mortar:
   In its most general and basic form, this is referred to as Portland cement, or Type One.

2. High performance mortars:
   This category in the wastewater environment has been dominated by Calcium Aluminate, and Pure Fused Calcium Aluminate.

Purpose of Study
The purpose of this study is:

- to test Calcium Aluminate (both traditional and Pure Fused)
- to test next-generation Epoxy-Modified Mortar
- to compare the chemical resistance of Calcium Aluminate and next generation Epoxy-Modified Mortar in an acidic environment typically found in a wastewater system

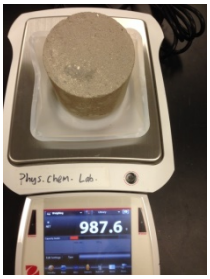
Study Design
H_2SO_4 (sulfuric acid) is the acid that will be tested in this study, because, as described above, this is the acid that is present in the wastewater system.

This is an accelerated test that will use 31% (5.63 M) sulfuric acid. This is also the typical concentration of car battery acid.

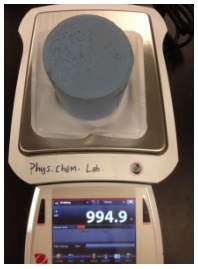
Cured material samples will be immersed in H_2SO_4.

Each sample will start out at approximately the same weight and size. Samples will be weighed weekly to determine their respective weight loss based on the acid corrosion. Weekly observations will be carried out for seven consecutive weeks.

Initial Material Samples



Sample 1
Calcium Aluminate
987.6g

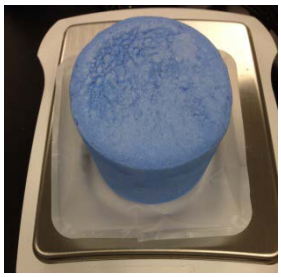


Sample 2
Epoxy-Modified Mortar
994.9g

Sample 3
100% Pure Fused Calcium Aluminate
981.1g

After One Week of Exposure to H_2SO_4

Sample 1
Calcium Aluminate
692g

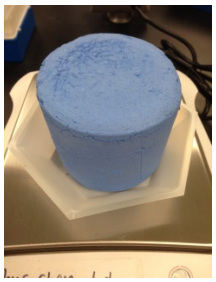


Sample 2
Epoxy-Modified Mortar
1050.2 g

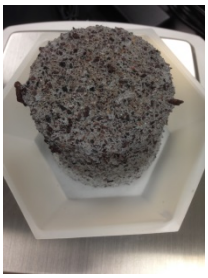
Sample 3
100% Pure Fused Calcium Aluminate
745.9

After Two Weeks of Exposure to H_2SO_4

Sample 1
Calcium Aluminate
534g



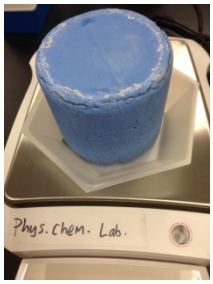
Sample 2
Epoxy-Modified Mortar
1052.5g



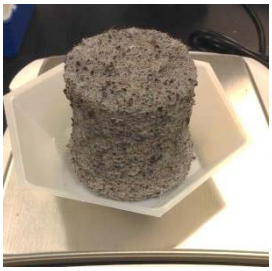
Sample 3
100% Pure Fused Calcium Aluminate,
617g

After Three Weeks of Exposure to H_2SO_4

Sample 1
Calcium Aluminate
433.6g



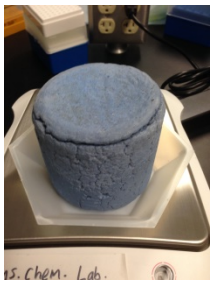
Sample 2
Epoxy-Modified Mortar
1059.1 g



Sample 3
100% Pure Fused Calcium Aluminate
531.0g

After Four Weeks of Exposure to H_2SO_4

Sample 1
Calcium Aluminate
365.1g



Sample 2
Epoxy-Modified Mortar
1054.1g

Sample 3
100% Pure Fused Calcium Aluminate
474.7g

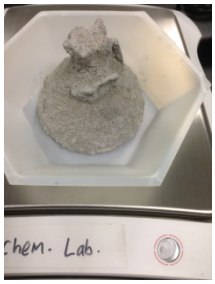
After Five Weeks of Exposure to H_2SO_4

Sample 1
Calcium Aluminate
315.6g

Sample 2
Epoxy-Modified Mortar
1064.5g

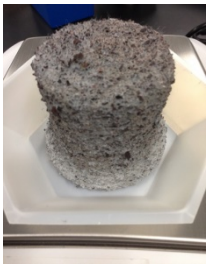
Sample 3
100% Pure Fused Calcium Aluminate
432g

After Six Weeks of Exposure to H_2SO_4



Sample 1
Calcium Aluminate
275.7g

Sample 2
Epoxy-Modified Mortar
1063.6g



Sample 3
100% Pure Fused Calcium Aluminate
393.0g

After Seven Weeks of Exposure to H_2SO_4

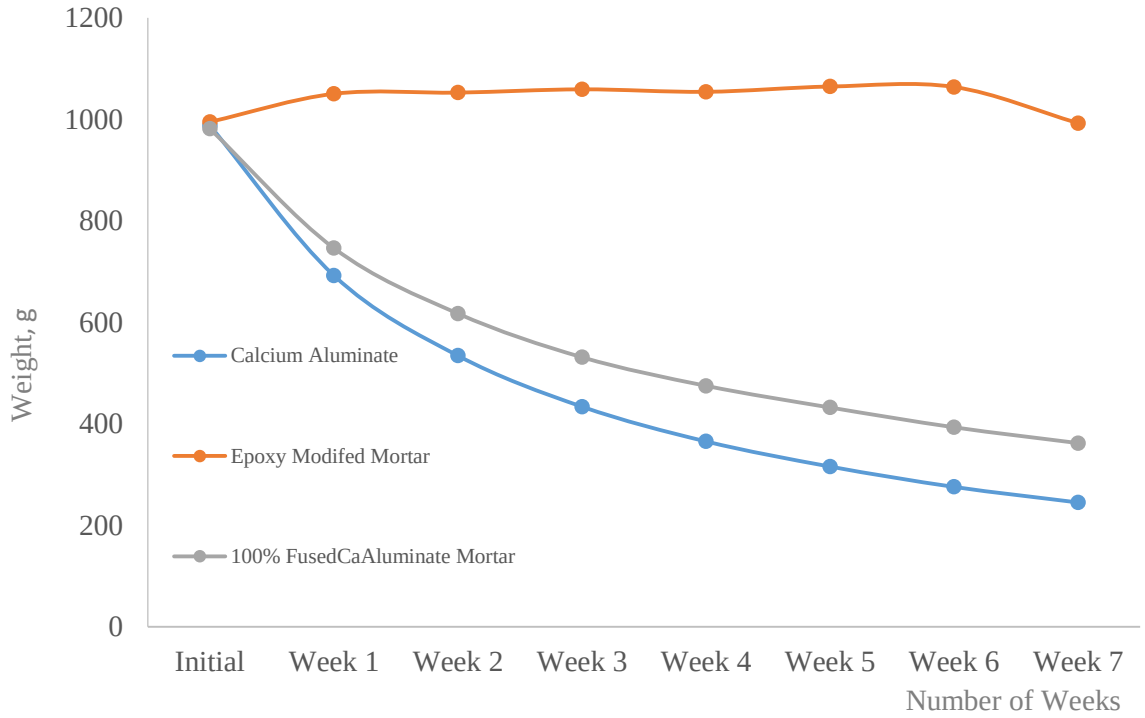
Sample 1
Calcium Aluminate
244.8g

Sample 2
Epoxy-Modified Mortar
992.3g*

Sample 3
100% Pure Fused Calcium Aluminate
361.7g

**After removing loose external scale, simulating power wash*

Weight Loss of Samples in 31% H_2SO_4



pH Testing of Final Samples

After the samples had been photographed and carefully weighed, their internal core pH levels were tested. Each sample was split down the middle. Samples were then tested using the following procedure:

- The samples were each moistened with clean, cool distilled water. A sealed new pack of litmus paper was opened and a strip was applied to each sample. Each strip was then each moistened further and saturated with distilled water.
- After waiting a short amount of time, the samples were observed, compared to the color scale provided by the litmus paper manufacturer, and photographed.

A pH level of seven is considered neutral. The higher (more basic/alkaline) the pH level is, the stronger (in terms of having a higher compressive strength) the sample remains, and the more it will potentially strengthen. Neutral or lower (more acidic) pH levels indicate that the sample will not continue to strengthen, and may in fact be weakening already.

A pH level of 10 or lower has been observed to cause or accelerate the corrosion of any embedded steel rebar within concrete. This would result in structural damage to the concrete over time, as the rebar corrodes.

After Seven Weeks of Exposure to H_2SO_4

Sample 1
Calcium Aluminate
pH 6-7

Sample 2
Epoxy-Modified Mortar
pH 12-13

Sample 3
100% Pure Fused Calcium Aluminate
pH 6-7

Summary of Observations

One hundred percent Pure Fused Calcium Aluminate showed better performance than Calcium Aluminate. Both, however, showed significantly poorer performance than Epoxy-Modified Mortar. Clearly, this material showed, by a significant amount, the best performance in 31% H_2SO_4.

1. Weight loss as a percentage of original weight after seven weeks:
   - Calcium Aluminate: 75%
   - Epoxy-Modified Mortar : 0.3%
   - 100% Pure Fused Calcium Aluminate: 63%

2. Observed pH levels after seven weeks:
   - Calcium Aluminate: pH 6-7
   - Epoxy-Modified Mortar : pH 12-13
   - 100% Pure Fused Calcium Aluminate: pH 6-7

Conclusions

It is clear that Pure Fused Calcium Aluminate performed better than traditional Calcium Aluminate, however, Epoxy-Modified Mortar performed significantly better than both of the other materials.

Side-by-side results after seven weeks of exposure to H_2SO_4:

Calcium Aluminate
75% Weight Loss
pH 6-7

Epoxy-Modified Mortar
0.3% Weight Loss
pH 12-13

100% Pure Fused Calcium Aluminate
63% Weight Loss
pH 6-7

The Epoxy-Modified Mortar showed significantly lower weight loss over the seven weeks, and showed the highest final pH reading. This indicates that it held up significantly better, but also that, due to the higher pH, it remained more structurally sound. A higher pH also indicates less impact on any embedded rebar within or behind the Epoxy-Modified Mortar.

Study conducted by Florida Atlantic University, June 2016. Epoxy-Modified Mortar provided by CLADLINER.
For more information or details on the Epoxy-Modified Mortar provided call 702.516.7661 or visit www.cladliner.com.