Leaching of Calcium from Concrete in Acidic and Sulfate Environments

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Abstract:
A total of 24 concrete specimens were placed in chemical solutions at room temperature. Both dry and wet concrete specimens (75mm x 150mm) were immersed in six chemical solutions. The pH of the solutions varied from 2 to 7. Changes in weight, appearance of solution and specimen and leaching of calcium were monitored at the end of every measurement cycle. The EDTA titration analysis was used to quantify the amount of calcium leached. The weight change and amount of calcium leached from dry and wet concrete specimens have been quantified. During the period of testing, wet concrete showed the highest weight gain of about 1.1% in both H_2SO_{4} at pH 4 and 2% Na_2SO_4 solution, while the dry specimen had the highest weight gain of 1.4% in 2% NaCl.

1. Introduction

Understanding the environmental effects on cement concrete materials is becoming important for designers and material developers. Effects of acid and sulfate attacks and leaching of calcium from concrete has not been fully examined. There is lack of available data on calcium leaching and its relationship to weight change in the test specimens. This study focused on quantifying the amount of calcium leached during chemical attack on concrete and its relationship to weight change. The calcium content in the hydrated cement system is critical for the integrity of the cementitious materials and its performance; hence, if calcium is leached during chemical attack it must be documented.

2. Objective

The overall objective was to quantify the changes in concrete under acidic and sulfate environments. The specific objectives are (1) to quantify the weight change and total calcium leached from the concrete specimens and (2) to determine the relationship between the weight change and the total calcium leached.

3. Experimental Program

Dry and Wet cylindrical concrete specimens (75 x 100 mm) were used in this study. Dry concrete specimens were immersed in selected chemical solutions after 28 days of curing, whereas the wet specimens were first immersed in a water bath for 28 days before testing. At least two specimens were tested under the same testing condition and the solutions were replaced every three months (cycle) or as needed based on the change in the pH of the solution. The liquid-to-solid ratio was approximately 1:1 by weight that was used in this study. Sulfuric acid (pH of 2 and 4), sodium sulfate (0.5% and 2%), hydrochloric acid (pH of 2) and sodium chloride (0.5%) solutions were selected and the tests were performed at a constant pH. The change in weight, dimensions, and total calcium leached in the solution were monitored at regular intervals.

4. Results And Discussions of Test Results

During the testing program, in addition to the visual observation, the amount of calcium leached and changes in weight of the specimens were monitored regularly during this study.

4.1 Weight Change: The percentage of weight change with immersion time is shown in Fig. 1 for a period of 900 days. The highest weight gain was observed in the first 100 days. Continuous weight gain was observed in the following solutions: HCl (pH 2); H_2SO_{4} (pH 4); 2% NaCl; 0.5% and 2% Na_2SO_4. In the wet group, the maximum weight gain was observed in 2% Na_2SO_4 (1.15%). In the dry specimens, the maximum weight change of 1.43% was observed in 2% NaCl solution. In general, the weight gain was higher in dry concrete (with comparable chemicals) due to the unfilled voids compared to wet specimens where voids are filled with water.

4.2 Leaching of calcium: In all of the specimens, the amount of calcium leached increased with time. The calcium leached was in the range of 0.05% to 0.25% (based on the initial weight) during the 900 days of immersion. Calcium leached from dry specimens was more than from wet concrete. This was because the dry specimens were richer in calcium than the water saturated specimens, where the saturation process would have removed some of the calcium. For both dry and wet concrete specimens, the initial rate of calcium removed was higher in HCl (pH 2), NaCl (2%)

and Na_2SO_4 (2.0%) compared to H_2SO_4 (pH 4) and Na_2SO_4 (0.5%). It was also observed that the initial rate of calcium removal might be different from the quantity of calcium removed over a longer duration of chemical immersion as in Fig 1.

5. Conclusions

The weight change and the amount of calcium leached were determined for two groups of concrete specimens immersed in six different chemical solutions for a period of 900 days. The chemical solutions included sulfuric acid, sodium chloride and sodium sulfate. Based on the experimental results and modeling, the following conclusions can be drawn:

- The weight change in dry specimens was slightly higher than wet concrete. Wet concrete specimens showed the maximum weight gain in H_2SO_4 pH 4 (1.15%) and 2% Na_2SO_4 (1.15%) solutions, while dry concrete specimens showed the maximum weight gain in 2% NaCl (1.43%) solution.
- The EDTA method of titration was used to determine the amount of calcium leached. For dry concrete specimens, the maximum amount of calcium removed was observed in 2% Na_2SO_4 solution, while wet concrete specimens showed the maximum removal of 0.19% calcium in 2% NaCl solution.
- A non-linear relationship exists between the weight change and the amount of calcium leached from the concrete.

6. Acknowledgement

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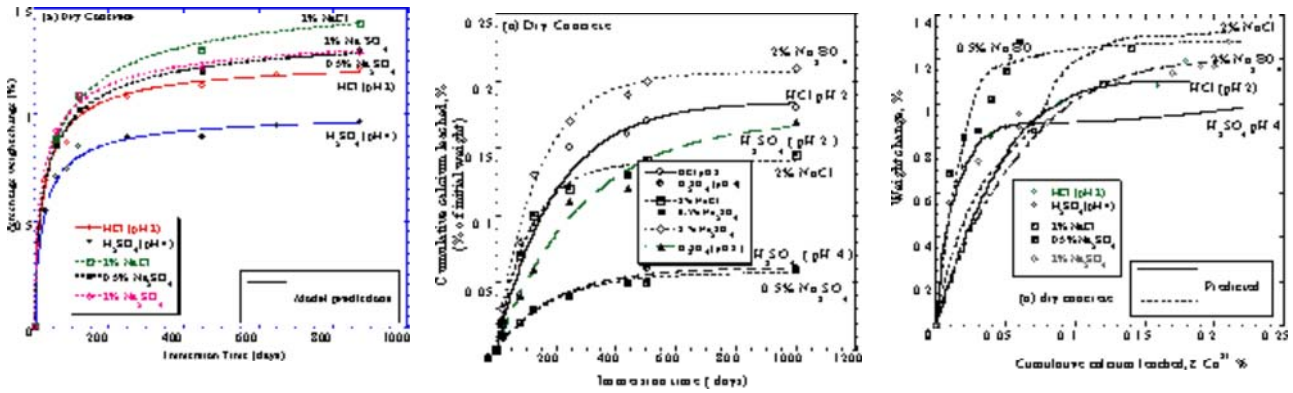

Fig. 1: Showing the weight change and cumulative calcium leached with time and their relationship for dry concrete.

If you have any questions, please contact **Dr. C.Vipulanandan**