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S2T02 - 2.2 Sewer infiltration and exfiltration

ICUD-0200

HRC method to measure concrete sewer pipe corrosion rate induced by sulphuric acid environment: temperature and pH

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Summary

Corrosion of concrete sewer pipes as induced by sulphuric acid attack is a recognised problem which leads to premature collapse of pipes with further significant cost implications. To promote pro-active sewer management, easy and robust models require development based on reliable calibration data. This paper focuses on laboratory experiments of establishing concrete pipe corrosion rate by submerging test samples in a 0.8pH and a 1.5pH sulphuric acid aqueous solution for 120 days under 15ºC and 25ºC temperature regimes. The result deliver understanding of the interaction between the acidity, temperature and corrosion levels which can be further incorporated into a model.

Introduction

The concrete sewer pipe structural vulnerability is dominantly addressed by the microbially induced concrete corrosion (MICC; Parker 1945, Vollertsen and Nielsen 2008), where this knowledge has yet to be transferred into an easy to use support tool for wastewater managers. Currently, the replacement and rehabilitation cost £85M-$300B in UK, Germany, USA & Australia, incurred in dealing with corrosion caused collapse of concrete sewer pipes.

Methods and Materials

A total of four containers with diluted sulphuric acid solution have been subjected to constant temperature regimes resulting in four conditions: (1) 15°C, 0.8pH, (2) 25°C, 0.8pH, (3) 15°C, 1.5pH, and (4) 25°C, 1.5pH, improving on methods of Gutierrez-Padilla et al. 2009 and Nandi et al. 2013. A total number of 168 cubes, measuring 50x50x50mm each, were used in these experiments. Each cube was cut from a brand-new circular concrete pipe using a diamond-blade rotating saw to highest dimensional precision possible. The cubes were allowed to cure in the sulphuric acid solutions for a period of 120 days, subsequently extracted in intervals and analysed.

Before commencing the sulphuric acid treatment each cube was dried in an industrial oven at 100°C for 24h and left to cool for 1.5h at 20°C. Further, the cube's physical measurements including mass were recorded (+/- 0.5g). A High-Resolution Camera (HRC, +/- 0.002mm) was used to capture the cube's roughness height in 2D format. Upon completion of the sulphuric treatment each cube was gently rinsed and washed, dried, cooled, measured and image captured with HRC. Corrosion rate was estimated as the average of difference between top vertex-to-vertex plane roughness height standard deviation before and after the treatment.

Results and Discussion

Before treatment, the average cube mass was 292g, with density of 2.32g/cm3, and standard deviation of the edge roughness at the top plane of 0.029mm. After treatment, samples showed soft and hard white formations – gypsum and ettringite (Mori et al 1991), these values on average were measured as 240g, 2.65g/cm^3 and 0.089mm, respectively (Fig. 1), and impact considerably tensile strength of concrete.

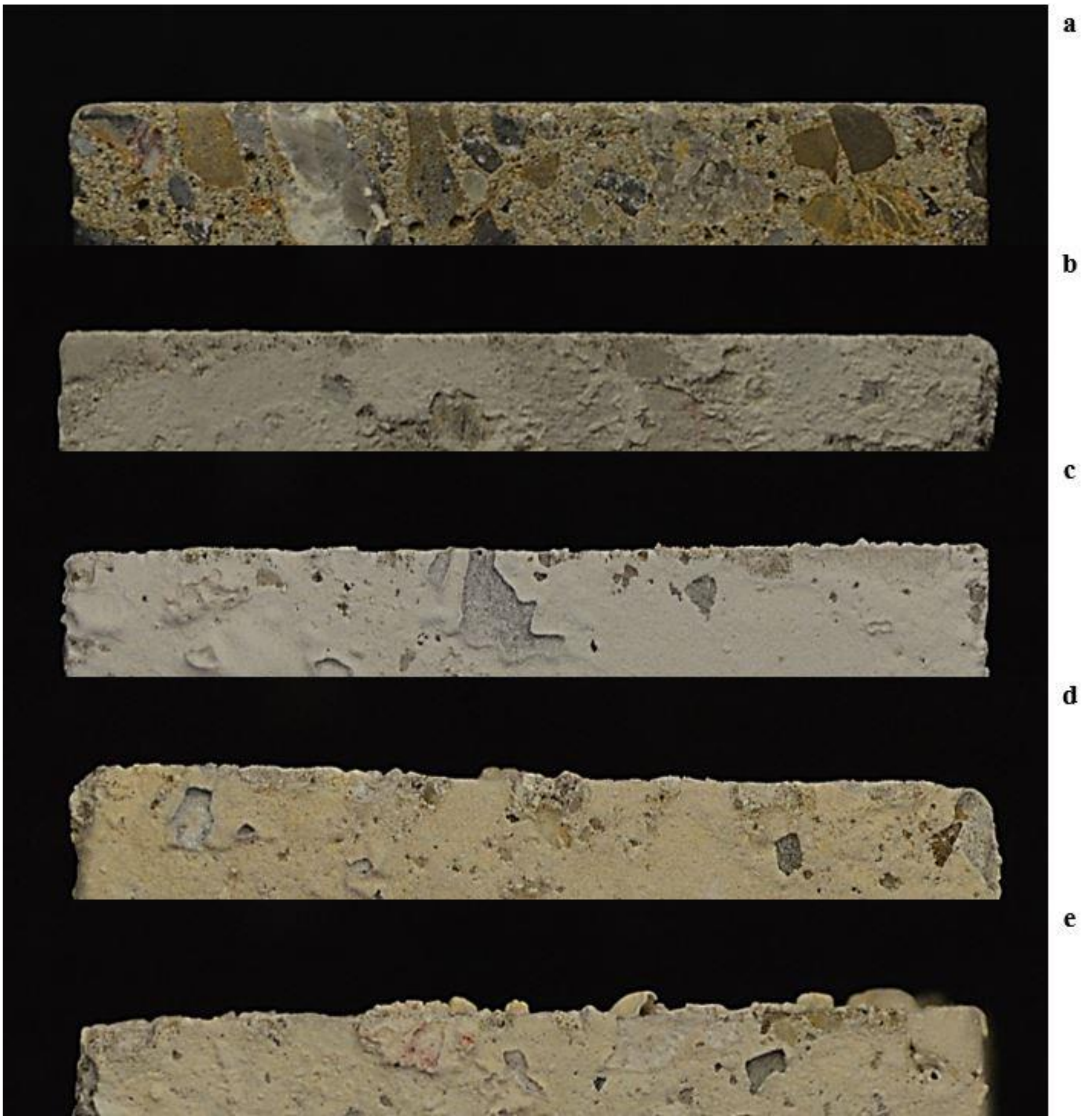

Fig. 1. Cube's roughness after sulphuric acid solution treatment under condition 2, in 7 days (a), 22 days (b), 50 days (c) 100 days (d) and 120 days (e).

Under all conditions between 2-14 days, when the corrosion process just begins to commence, an increase in corrosion rate (*k*) at day 4 was observed, with further rapid decrease in day 9 (Fig. 2), also reported by Nandi et al. 2013, Wells and Melchers 2014, Jiang et al. 2015 and Romanova 2016. In 14-120 days *k* increases by 0.02-0.25mm. For conditions 1 and 2, T=15°C, common for European sewers, there was a pronounced peak of *k* increase at days 39 and 50, respectively. These are thought to be governed by the time when the acid breaks the aggregate bond of the concrete. For conditions 3 and 4, T=25°C, common for countries with hot climate conditions, the corrosion process was established generally faster and continued to rapidly grow.

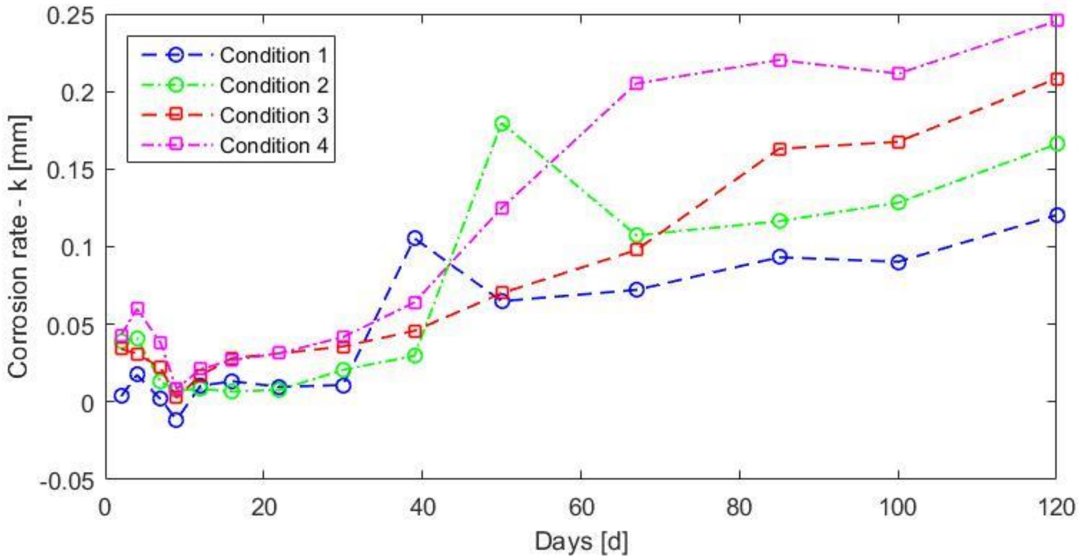

Fig. 2. Average corrosion rate for different experimental conditions.

Conclusions

It can be concluded that: (i) at early stages the corrosion process is unstable and therefore merits further examination; (ii) corrosion establishes faster in the presence of higher temperatures at low pH; (iii) the corrosion process is non-geometrical within 120 days and needs to be studies at a micro-chemical level; (iv) concrete mass, density and compressive strength have peculiar behavior and needs further examination; (v) corrosion rate model based on these results require further calibration before can be incorporated into the failure prediction model.

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