pH Sensing System for Evaluation of Acid Permeation in Cement Based Coatings for Wastewater Assets

Introduction

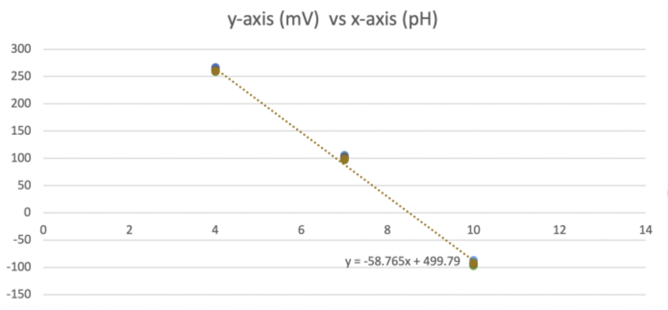
Acid Permeation of sewer pipe coatings emerged as an important parameter to be evaluated for long-term performance monitoring (LTPM) of calcium aluminate cement (CAC) and geopolymer coatings. Measurement of pH condition was identified as a good indicator of acid permeation through CAC and geopolymer coatings. This factsheet briefly presents an overview of the development of a sensing system for pH measurements of CAC and geopolymer coatings to be used in traversable sewer pipes.

Sensing System Development

The iPipes team at the University of Technology Sydney (UTS) used pH sensors to assess the acid permeation condition of the applied CAC and geopolymer coatings. As a practical solution, we have developed a sensing system for surface pH measurements. It could be used as a pH depth profiling sensor by integrating the sensor and processing unit with a drill. After reviewing commercially available sensing technologies for micro-invasive pH profiling, we have short-listed a spear tip type pH probe as a potential candidate. The sensor's electronics unit consists of an analog to digital converter, which is used for signal processing by converting the raw analog data of the sensor measurements to a digital value. A 3D printed PVC enclosure was designed and fabricated for housing the pH sensor electronics unit as shown in Fig. 1. The sensing unit is connected to the graphical user interface (GUI) tablet through a USB cable.

Fig 1. pH sensing system prototype.

Laboratory experiments were conducted to calibrate the pH sensing system by exposing the probe tip to different pH buffer solutions; pH levels of 4, 7 and 10. Fig. 2 shows the calibration plot having pH levels of the buffer solution in the x-axis and the corresponding millivolt (mV) analog signal in millivolt (mV) from the sensor.



After calibration, multiple sensor measurements were taken in buffer solutions having pH levels 4, 7, and 10. The buffer solution pH levels were used as the benchmark. Table 1 presents the buffer solution pH levels versus the sensor measurements.

Table 1: Buffer solution pH levels versus pH sensor measurements

Sensor Measurement index	Buffer Solution pH=4	Buffer Solution pH=7	Buffer Solution pH=10
1	3.818	6.906	9.817
2	3.92	7.049	9.939
3	3.845	6.995	9.935
4	3.82	7	9.953
5	3.772	6.963	9.94
6	3.928	7.063	9.974
7	3.906	7.019	9.92
8	3.893	7.035	9.912
9	3.864	6.965	9.896
10	3.907	7.043	9.901

From the above table, the mean pH sensor measurements for buffer solution of pH level 4 is 3.87, for buffer solution of pH level 7 is 7.01, and for the buffer solution of pH level 10 is 9.92. This shows that the pH sensor measurements are reasonably accurate.

Software and GUI Developments

To collect the raw pH sensor signals and process them to obtain meaningful information, software algorithms were developed using open source robotics middleware suite. The software was installed on a hand-held tablet running Linux and displays the pH sensor measurements in real-time, as shown in Fig. 2.

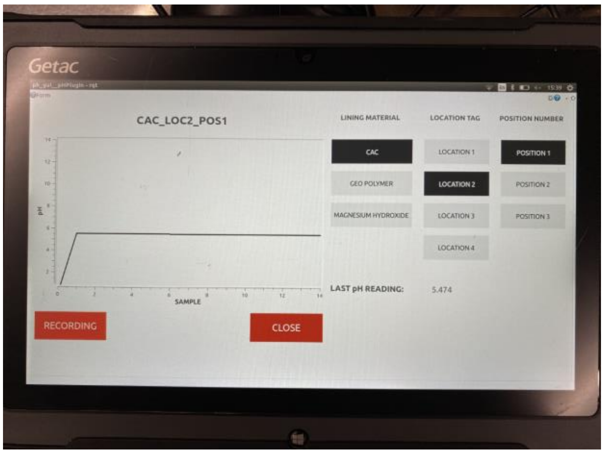


Fig 2. Hand-held tablet for displaying the real-time pH sensor measurements.

The tablet's custom-designed software allows users to select lining material, location, and position by simply touching the respective buttons. The tablet can be used continuously for up to four hours and can store pH sensor measurement data for offline analysis.

Field Testing and Validations

The UTS team has trained the Sydney Water contractors from Interflow to use the pH sensor and hand-held tablet for sensor data visualisation. The field tests were conducted at the Sydney Water NSOOS site at Toongabbie, Sydney on 2nd December 2020. The Interflow personnel entered the sewers with the sensor and took measurements. Fig. 3 shows the lowering of the sensors into the sewer and taking sensor measurements inside the sewer pipe.

(a) (b)
Fig 3. Field testing. (a) Lowering the sensing system inside the sewer, (b) Interflow personnel taking sensor measurements.

In addition to CAC and geopolymer coatings, in the field tests, measurements were taken of magnesium hydroxide coatings. A total of 9 measurements were taken on CAC coatings. 3 measurements from the crown region, 3 from the right-side tidal region and 3 from the left-side tidal region. On the geopolymer and magnesium hydroxide coatings, 12 sensor measurements were taken. 4 measurements from the crown region, 4 from the right-side tidal region and 4 from the left-side tidal region. Fig. 4 shows the pH sensor measurements with error bars denoting the standard deviation of sensor measurements for measurements at each coating region.

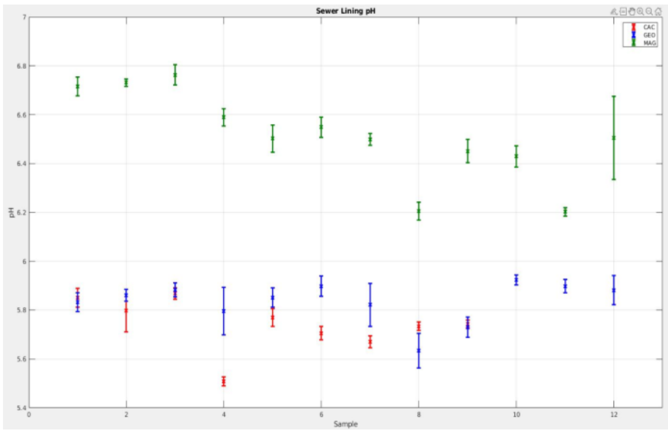


Fig 4. pH sensor measurements taken in real sewers.

In the field, pH test strips were used to verify the pH sensor measurements. The pH measurements taken with the pH strips in the CAC and geopolymer regions indicated that the pH levels were approximately 6, while the measurements taken in the magnesium hydroxide region indicated that the pH levels were approximately

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7. In the field test, the pH sensor measurements aligned with the colour indicator of the pH strip. This provides a simple in-field test that indicates accurate readings.

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