POF センサーを利用した鋼構造物の腐食モニタリングに関する基礎的研究

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1.Introduction

Health monitoring of engineering infrastructure has received more and more attention. Steel corrosion is a major structural defect for steel structures such as pipes and plates. Although various methods such as measuring weight loss and electrical approaches have been utilized for steel corrosion detection, the lack of real-time corrosion measurement approaches limits their application. Instead, the corrosion can be monitored by detecting the color change. The plastic optic fiber (POF) sensor can detect color and its change on the surface of any engineering material and has the ability to provide real-time monitoring. Therefore, the POF sensor could be a potential candidate for steel corrosion detection. In this article, the sensing principle and laboratory accelerated corrosion tests using uniquely developed POF sensors are discussed.

2. Principle of plastic optical fiber sensor

A pipe-type sensor is a sensor with multiple optical fibers inserted in a single pipe, as shown in Fig.1. Each optical fiber plays the role of a light source or light receiver. The plastic pipe with an inner diameter of 3 mm is used and seven 1 mm optical fibers are installed in the pipe. In this study, five fibers are used as light sources, and two as light receivers, reading the light reflected from the object. The space ahead of the seven POF is filled with adhesive whose thickness is 3mm. This will achieve the best possible reception of the POF signal.

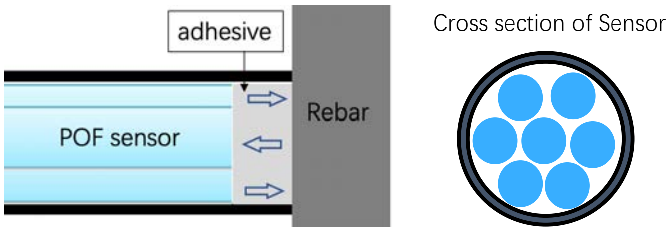

Fig.1　Pipe-type sensor for rebar

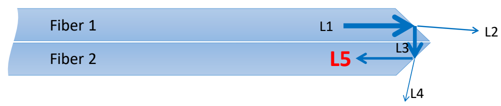

Fig.2　RR sensor

Another sensor used in this experiment consists of two plastic optical fibers (1 mm in diameter) bonded together with the tips of the fibers cut at 45 degrees each[1]. As shown in Fig. 2, when the light from the light source reaches the first fiber's tip, a portion of it passes through the cut surface as refracted light L2, while the rest is reflected and enters the second fiber as L3. The light entering the second fiber reaches the cutting surface and is divided into refracted transmitted light (L4) and reflected light (L5), and finally, L5 is recorded in the optical data logger. It is well known that the magnitude of L5, which is recorded by two refractive transmission and reflection processes at the fiber split surface, is affected by the difference between the refractive index of the fiber (1.49) and the refractive index of the surrounding material (1.0003 for air and 1.33 for water). Specifically, as L5 rises, the contact area between the cutting surface of the fiber tip and air increases, and as it falls, the contact area with water increases. This sensor is called an RR sensor because it senses light based on its refractive and reflective properties.

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3. Electric corrosion experiment

A cylindrical specimen of cement paste (non-shrink mortar, W/C=18%) with a diameter of 10 cm and a height of 20 cm was prepared. RR sensors were installed at a distance of 1 cm from the bottom of the specimen, one at an interval of 1 cm, for a total of 6 RR sensors to monitor the water intrusion. The pipe-type sensor was installed on the rebar surface to monitor the development of corrosion on the rebar surface. In order to vary the insertion depth of the rebar, two guide frames (made using a 3D printer) were prepared, one for fixing the rebar at 2 cm from the bottom of the specimen 1 and the other for fixing the rebar at 4 cm from the bottom of the specimen 2.

The pipe-type sensor was connected to a conventional data logger and compared with the measurements conducted by an image processing application software[2]. As shown in Fig.4, during the measurement, the first half of the data was not available due to a computer failure. It can be seen that from the second half of the measurement, the *R*/*A* (*R* indicates the intensity of red light, *A* indicates the intensity of red, green and blue combined) values recorded by the optical data logger and by the image processing software gradually increased. Besides, the *R*/*A* values calculated from the results obtained by the two different recording methods, showed an increasing trend almost at the same time.

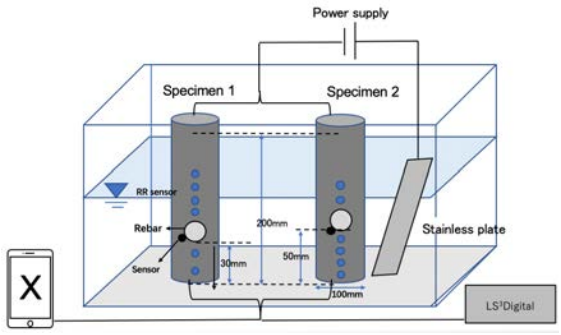

Fig.3 Overview of the reinforcement concrete experiment

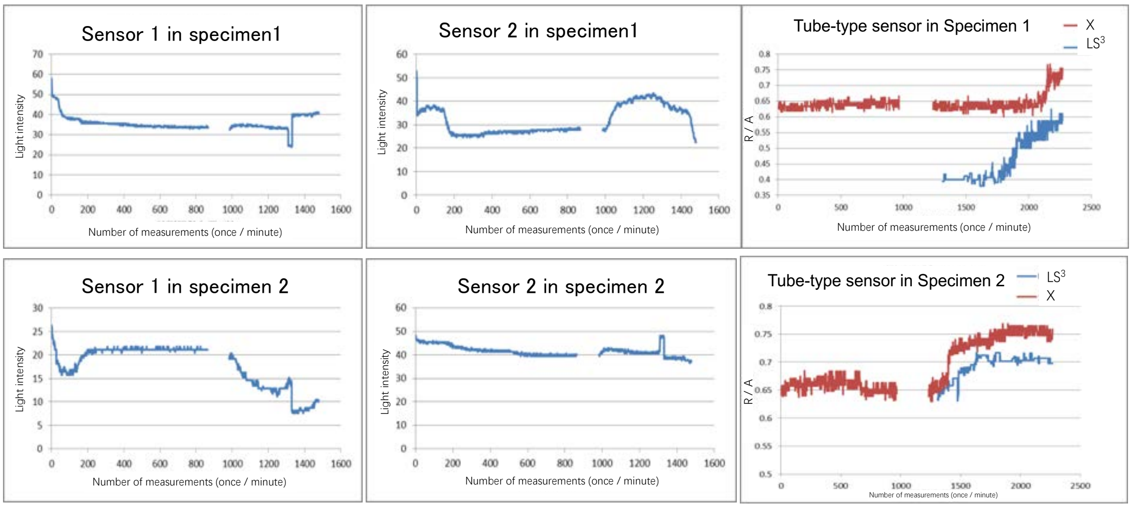

Fig.4 Moisture movement by RR sensor and corrosion captured by pipe-type sensor.

4. Summary

It was found that the POF sensors can be used for not only for water penetration in a porous media but also for corrosion detection of rebars in a matrix material such as cement. The success in monitoring such data using POF sensors and the newly developed image processing application software promises an effective monitoring system at a relatively low cost.

5. Reference

1) Akutagawa, S., Machijima, Y., Sato, T. and Takahashi, A. 2017. Experimental characterization of movement of water and air in granular material by using optic fiber sensor with an emphasis on the refractive index of light, Proceedings of the 51st US Rock Mechanics / Geomechanics Symposium, ARMA 17-313, San Francisco.

2) 芥川真一・林稔・松村匡樹・土本真史：特願 2020-065363，状態変状検知装置，状態変状検知方法および状態変状検知プログラム，2020.3.