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Abstract

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Karim Bouzaffour [1], Philippe Talbot [1], Benoit Lescop [1], Stephane Rioual [1,*], Yannick Falaise [2], Cheikh Sarr [2], Sylvain Chataigner [2] and Laurent Gaillet [2]

[1] Lab-STICC, University Brest, CNRS, UMR 6285, 29200 Brest, France; karim.krimbouch@gmail.com (K.B.); philippe.talbot@univ-brest.fr (P.T.); benoit.lescop@univ-brest.fr (B.L.)
[2] MAST-SMC, Université Gustave Eiffel, 44344 Bouguenais, France; yannick.falaise@univ-eiffel.fr (Y.F.); cheikh.sarr@univ-eiffel.fr (C.S.); sylvain.chataigner@univ-eiffel.fr (S.C.); laurent.gaillet@univ-eiffel.fr (L.G.)
* Correspondence: rioual@univ-brest.fr
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Abstract: Steel corrosion in concrete infrastructures is of worldwide interest. This paper reports the monitoring of concrete prestressed bridge infrastructures by autonomous sensors based on the RFID technology. Embedded autonomous sensors in concrete were produced for this purpose and tested in a laboratory environment. Subsequent tests in real environments are in progress.

Keywords: corrosion monitoring; RFID sensor; prestressed concrete bridge

1. Introduction

Steel corrosion in reinforced and prestressed concrete structures is recognized as a global issue that causes widespread damages ranging from crack formation to an ultimate structural collapse. It is often associated with carbonation and/or chloride ingress since these two actions lead to the degradation of the initial passive protective layer on steel. Within this context, there is a real interest in monitoring the corrosion of steel in concrete and the related parameters such as pH and chloride ingress using embedded wireless autonomous sensors in the infrastructures.

Among the possible solutions, RFID (Radio Frequency Identification)-based sensors are particularly attractive since it is possible to develop wireless battery-less sensors with a few dimensions that are sensitive to steel corrosion. The absence of a battery and a cable facilitates their integration in concrete during construction or maintenance/repair operations and allows for a long service lifetime. The first application of such sensors was in atmospheric corrosion monitoring [1]. The principle of the method is based on an RFID tag which electromagnetically interacts with a thin conductive metallic sensitive layer. The variation of the electrical resistance of this sensitive layer, steel in this case, induced by corrosion modifies this interaction, providing some information about its corrosion. It was subsequently proved that such sensors can be embedded in concrete to obtain some information about corrosion at different depths [2]. In particular, embedding a corrosion sensor at a 3 cm depth which serves as an alert for the corrosion of rebars located at larger depths was realized. Several failures of prestressing strands due to the penetration of water/chloride into HDPE (High-Density Polyethylene) ducts have been reported on bridges in France since 2014 [3]. This present study, therefore, focused on the application of RFID sensors for the monitoring of prestressing steel corrosion in such ducts.

2. Materials and Methods

Prior to the realization of RFID-sensitive antennas, electromagnetic simulations were conducted using the software HFSS (High-Frequency Structural Simulator) from ANSYS. It utilizes tetrahedral mesh elements to determine the solution to a given electromagnetic

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problem. The aim of such simulations was to ensure an interrogation of RFID tags in a specific environment, inside the ducts, and to prove the sensitivity to either corrosion phenomena or deformation. After their realization, sensors were produced and tested in laboratory conditions.

3. Discussion

As it will be presented at the conference, RFID corrosion sensors were successfully placed during inspection operations in HDPE ducts and interrogated from outside, thereby demonstrating the effectiveness of the method. These pioneering investigations also highlight the specificity of this application concerning the geometrical arrangement of strands in the ducts. Indeed, instead of a uniform distribution, they are eccentrically located, resulting in strands in direct contact with the HDPE duct. This influences the corrosion process (since strands are not protected from grout at the HDPE surface) and also the operating conditions and locations of sensors. In particular, the reading distance of sensors, i.e., the distance between the reader and the sensors, is impacted by this phenomenon. To discuss the sensitivity of such sensors, accelerated corrosion tests were also performed in the laboratory. The results will be discussed at the conference.

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References

1. Rioual, S.; Lescop, B.; Pellé, J.; De Alkmim Radicchin, G.; Chaumatn, G.; Bruni, M.D.; Becker, J.; Thierry, D. Development of low-cost RFID sensors dedicated to air pollution monitoring for preventive conservation. *Herit. Sci.* **2022**, *10*, 124. [CrossRef]
2. Bouzaffour, K.; Lescop, B.; Gallée, F.; Talbot, P.; Rioual, S. Development of an embedded UHF-RFID corrosion sensor for monitoring corrosion of steel in concrete. *IEEE Sens. J.* **2021**, *21*, 12306–12312. [CrossRef]
3. Godart, B.; Gaillet, L.; Van Schoors, L.; Labourie, L.; Germain, D.; Vaurigaud, B. Recent failures of external prestressing grouted tendons: The paramount role of the HDPE duct. In Proceedings of the IABSE Congress, Resilient Technologies for Sustainable Infrastructures, Christchurch, New Zealand, 3–5 February 2020; Abu, A., Ed.; IABSE Publisher: Zurich, Switzerland, 2020; pp. 775–782.