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Sensor Development for Corrosion Monitoring Of Reinforcement Steel

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Abstract: In this research we have discussed the sensor development for corrosion monitoring of reinforcement steel. The presence of chloride ions is one of the main causes of corrosion of steel in concrete. We have also discussed wireless sensor networks. The preventive measures have also been discussed in the end of the paper.

Keywords: Wireless sensor, Non-destructive testing, Corrosion monitoring, steel.

I. Introduction

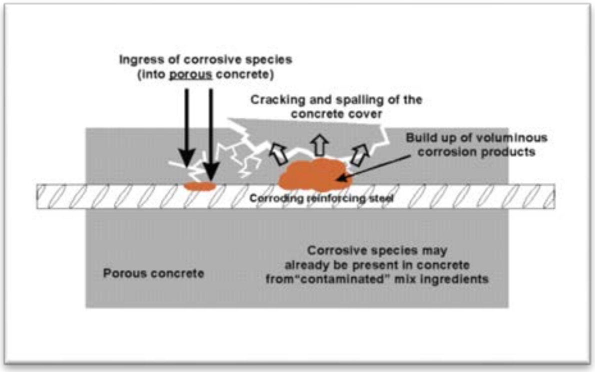
Wireless sensor networks is a kind of step in the transition to the next era, when the computers are directly connected to the physical world and be able to guess the desire of users, and make decisions for them. A wireless sensor network (WSN) can be characterized by the use of a large number of sensor nodes, with the ability to communicate. These nodes can be placed inside the phenomenon to be analyzed or close to it, unlike the traditional sensor networks.

II. Subject

Corrosion is a type of decay which can be easily found on metal works. The steel oxidizes when in contact with moisture or harmful gases, thus necessitating care to extend their durability. Fiber optic sensors can detect moisture expansion and cracks in concrete structures, allowing engineers to observe the condition of the structure and the forecast life of the structure. Reinforced concrete corrode, which ultimately leads to the complete destruction of the structure[1].

The first stage moisture penetrates into the concrete. Upon reaching the reinforcing structures, high concentrations of these elements begin to attack the passive layer of the hydrated iron oxide which protects the metal from corrosion. Rust starts converting a compound of trivalent iron to the divalent and the volume of this structure are expanded from five to 10 times. Enormous pressure begins to increase, resulting in cracks begin to develop. If this process continues, the structure ultimately fails.

[1] Hu, W., Cai, H., Yang, M., Tong, X., Zhou, C., & Chen, W. (2011). Fe–C-coated fibre Bragg grating sensor for steel corrosion monitoring. Corrosion Science, 53(5), 1933-1938.



Therefore, monitoring of corrosion of concrete allows anticipating potential problems with concrete structures. Nevertheless, the identification of the specific causes of corrosion can be difficult, as there are several reasons for the development of this process:

- Wear and cracks may be the result of poor concrete mix,
- Incompetence, inadequate design,
- Shrinkage
- Chemical and environmental exposures,
- Physical or mechanical damage,
- Corrosion of reinforcing steel (RS).

Here we present a roadmap for the development of a set of sensors and the associated detection systems reinforcing steel and corrosion damage degree at a time. The proposed system allows high resolution and will offer an accurate assessment of the concrete structure. In order to develop an approach, we examined the methodology corrosion detection, which has been carefully worked out over the last 20 years[2].

By understanding the stages of corrosion, we were able to develop special sensors to improve the accuracy of the approach. Firstly, we can control the penetration of moisture from the humidity sensors. Excessive moisture allows better chlorides penetrate the concrete, accelerating the corrosion process and causing a large volume expansion. Ultra-sensitive fiber optic pressure sensors can detect the extension and lock acoustic emission which is detected by a vibration sensor on the basis of the high frequency phase-shifted gratings[3].

[2] Karthick, S. P., Muralidharan, S., Saraswathy, V., & Thangavel, K. (2014). Long-term relative performance of embedded sensor and surface mounted electrode for corrosion monitoring of steel in concrete structures. Sensors and Actuators B: Chemical, 192, 303-309.

[3] Qiao, G., Sun, G., Hong, Y., Qiu, Y., & Ou, J. (2011). Remote corrosion monitoring of the RC structures using the electrochemical wireless energy-harvesting sensors and networks. NDT & E International, 44(7), 583-588

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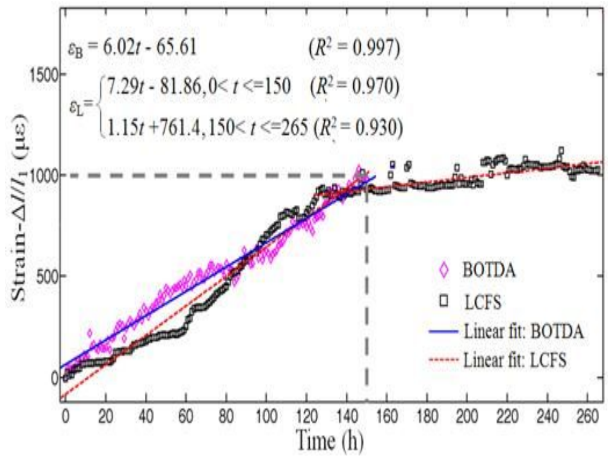

Figure: Sensors

TC600 Reinforcement Corrosion Detector

TC600 reinforcement corrosion detector is designed to assess corrosion of reinforced concrete structures and components of the method and the tracking voltage passes over the concrete surface potential difference.

III. Features

- Non-destructive testing of corrosion of reinforcing steel
- Detection of reinforcement corrosion using a field measurement of the potential difference
- The ability to store, view, delete and transfer data to a PC via USB and serial port
- Fast and accurate data processing
- Measured value display: 9 shades of gray or colorful graphics
- Constant support copper electrodes for measuring electrical potentials[4].

The reinforcing steel corrosion is one of the principal parent's causes of degradation of reinforced concrete structures, especially when the structure is exposed to ambient aggressive. The most important corrosive agents in Corrosion of the reinforcement are carbon dioxide and ions chloride. In marine environments, the chloride ions cause localized corrosion of steel, reducing the cross-section of men. On the other hand, the accumulation of product corrosion in the steel / concrete interface generates internal stresses expansion. In extreme cases the concrete cover can be completely destroyed.

Ag / AgCl Electrodes

In concrete structures damage caused by corrosion can be very high and the solutions to prevent and minimize such damage are generally expensive. Thus, prevention of corrosion phenomenon appears as one of the best options. The determination of the content of chlorides is usually done using the samplers' collection that obtained by drilling at various depths of the concrete. The samples are then subjected to attack Chemical and analyzed to determine the total content of chlorides. However, this method is destructive. The Ag / AgCl electrodes are widely used in the business analytical due to their sensitivity to chloride ions. However, their behavior in alkaline environments, as concrete (pH 12-13), has been little studied which indicates that factors such as temperature and the presence of bromide ions can affect the potential readings of electrodes of Ag /

[4] Lu, Y., Zhang, J., Li, Z., & Dong, B. (2013). Corrosion monitoring of reinforced concrete beam using embedded cement-based piezoelectric sensor. Magazine of Concrete Research, 65(21), 1265-1276.

AgCl. It is also reported in the literature [4] that sensors Ag / AgCl when used in concrete are stable only for short periods of time (three months)[5].

Despite these limitations the electrodes of Ag / AgCl continue to be the most suitable option for monitoring chloride content in reinforced concrete structures. This work aims to combine the potential of these electrodes to develop a sensor, strong, reliable, and simple to installing in reinforced concrete structures. The chloride sensor Ag / AgCl studied in this work was obtained by anodizing silver wires. The sensor has determined the chlorides contentment at various depths in mortar specimens and from the hence, build a chloride profile[6].

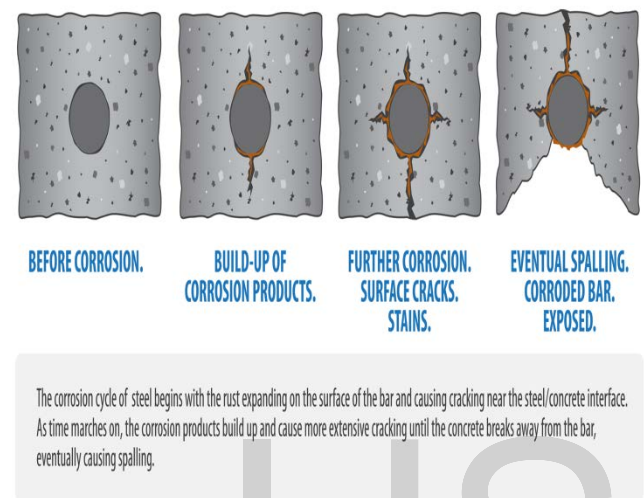

Figure: Galvanized Steel

IV. Factors Affecting Reinforcement Corrosion In Concrete

The well-known fact that the most intense corrosion of reinforcement in concrete in atmospheric conditions, effects observed at 70- 80% relative humidity, as this is provided to supply a sufficient amount of steel and water and oxygen, as well as Test specimens' mode periodic wetting and drying. Moreover, in the viewpoint of corrosion amplification, the most important time period during which the material removes water and, consequently, the part is released from its pores. For this reason, corrosion of reinforcement in concrete, almost all of the pore space is completely filled with moisture (e.g., during operation of products under water) flows is much slower than with 70-80% relative humidity. This fact is taken into account during the accelerated corrosion tests most characteristic modes of these tests - periodic wetting and drying of samples or stored at a relative humidity of about 70-80%.

[5] Sena da Fonseca, B., Castela, A. S., Silva, M. A., Duarte, R. G., Ferreira, M. G. S., & Montemor, M. F. (2014). Influence of GFRP confinement of reinforced concrete columns on the corrosion of reinforcing steel in salt water environment. Journal of Materials in Civil Engineering.

[6] Qiao, G., Sun, G., Hong, Y., Qiu, Y., & Ou, J. (2011). Remote corrosion monitoring of the RC structures using the electrochemical wireless energy-harvesting sensors and networks. NDT & E International, 44(7), 583-588.

Corrosion of reinforcement in concrete reduces the durability of concrete structures in corrosive acidic gases. The danger of this process is exacerbated by the fact that virtually difficult to control the degree of damage to valves operated designs.

Consider corrosion of reinforcement in concrete, which flows over a very long period of time. Assume that the concrete structure is a body defined thickness and concentration of the aggressive environment in the valve is retained almost unchanged. In this case, there is another way of modeling of corrosion of reinforcement in dense concrete. The concrete with the mixing water entering the corresponding calcium salt, the salt concentration is chosen based on the data of field surveys of structures operating in the shops of enterprises of petrochemical, often in the laboratory for process intensification her some increase, since the mechanism and the main features of reinforcement corrosion in this case unable to save [7].

Before we consider the indirect effect of organic corrosion inhibitors, it is necessary to prove the feasibility of their use in concrete, given the peculiarities inherent corrosion of reinforcement in concrete dense defect-free. In fact, although the supposed time - to restore the protective layer of concrete and paint - the protection of the exposed metal, nevertheless inhibitors should be administered in the concrete mix. Consequently, they are, firstly, it must not impair the properties and, secondly, should be maintained in the concrete unchanged that affect their inhibitory capacity[8]. This is particularly important factor for reinforcement corrosion in concrete with thin fissures where inhibitors can easily diffuse from the cement paste, as well as corrosion of the reinforcement with a thin layer of concrete, as already mentioned.

From the above it follows that the phenomenon of corrosion of reinforcement in concrete is very difficult. For predicting the state of the valve must be taken into account a large number of factors.

V. Conclusion

Protection attempts are generally directed to the steel coatings (galvanizing, painting). Other preventive measures such as reducing the permeability of the concrete, increasing the depth of concrete cover or elimination of chlorine ions by the use of sealants are applicable. Preventive measures have some degree of success but not comparable to cathodic protection. There is no significant relationship data between the severity of corrosion and the composition of the steel reinforcement. Generally the alloying elements can reduce the attack rate, but the balance between efficiency and cost is not well established.

[7] Calabrese, L., Campanella, G., & Proverbio, E. (2012). Noise removal by cluster analysis after long time AE corrosion monitoring of steel reinforcement in concrete. Construction and Building Materials, 34, 362-371.

[8] Hu, W., Cai, H., Yang, M., Tong, X., Zhou, C., & Chen, W. (2011). Fe–C-coated fibre Bragg grating sensor for steel corrosion monitoring. Corrosion Science, 53(5), 1933-1938.

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