# Characterizing of steel-cement interface for Corrosion Detection

**Kibraeb Gebreselassie and C. Vipulanandan, Ph.D., P.E.**
Texas Hurricane Center for Innovative Technology (THC-IT)
Department of Civil and Environmental Engineering
University of Houston, Houston, TX, 77204-4003
Email:kagebreselassie@uh.edu, cvipulanandan@uh.edu, Phone: (713) 743-4278

**Abstract:** Corrosion is the primary factor affecting the longevity and reliability of pipelines that transport crucial energy sources throughout the nation. The analysis of piezoresistivity properties at the interface level could determine the difference in the electrical resistance and capacitance of interfaces between cement paste and corroded rebar, and cement paste and non-corroded rebar. These piezoresistivity properties are used presence of corrosion at the steel-cement interface.

## 1. Introduction

Corrosion is a naturally occurring phenomenon commonly defined as the deterioration of a substance (usually a metal) or its properties because of a reaction with its environment. It is the primary factor affecting the longevity and reliability of pipelines that transport crucial energy sources throughout the nation. For the past two decades, there has been a tremendous amount of research focused on smart coatings for structural applications; coatings the can sense certain conditions and then respond (Wheat, 2012). These are coatings that typically contain one or more indicators that can sense condition such as corrosion and respond by means of changes in pH, color, fluorescence or a combination thereof (Wheat, 2012). In the industry of gas and oil, corrosion of steel casing in cement mortar or reinforced concrete is of concern because it requires almost immediate repairs and rehabilitation to extend the service life of the structures.

## 2. Objective

The objective of this study was to develop a electrical method to determine the presence of corrosion in cement mortar and/or reinforced concrete based on its piezoresistivity properties.

## 3. Literature Review

The literature reviews revealed that not much research work have been done so far regarding the piezoresitvity properties at the interface level between steel and its surrounding composite materials such as cement. Many research studies have been focused on coatings that typically contain one or more indicators that can sense condition such as corrosion and respond by means of changes in pH, color, fluorescence or a combination thereof (Wheat, 2012). The applicability of such coatings for the steel casing in oil wellbore is difficult and impractical to monitor the changes that the coatings may exhibit due to the inaccessible nature of wellbore.

## 4. Discussion

Cement specimens embedding two kinds of rebars have been prepared for laboratory tests to characterize the piezoresistivity properties of the interface between the rebar and the cement paste. The size of the specimens was cylindrical with diameter of 2 inches and height of 4 inches. Corroded and non-corroded rebars were used with the size of #3 and #4 respectively. Both rebar types had a length of 5 inches. Specimens were instrumented with 5 silver-paint wires connected to the embedded rebar and 2 silver-paint wires connected to the cement paste (illustrated in Figure 2). Water cement ratio of 0.4 was used. To improve the piezorestivity properties of the cement paste, carbon fiber with 0.075 % by weight of the cement paste was added. The electrical resistances and capacitance of the cement paste, rebar, and transitional contact between the cement paste and rebar were measured with impedance analyzer precision LCR meter. The equivalent circuit adopted based on expected behavior of the material under this study is shown in Figure 1. The total impedance of the equivalent circuit is given as follows:

$$Z = R_b + \frac{R_c}{1 + \omega^2 {R_c}^2 {C_c}^2} + \frac{R_i}{1 + \omega^2 {R_i}^2 {C_i}^2} - j\left(\frac{\omega {R_c}^2 C_c}{1 + \omega^2 {R_c}^2 {C_c}^2} + \frac{\omega {R_i}^2 C_i}{1 + \omega^2 {R_i}^2 {C_i}^2}\right)$$

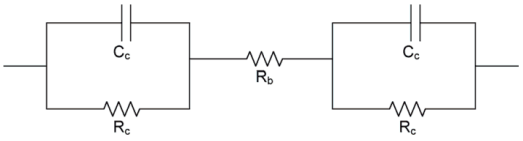


Figure 1 – Equivalent circuit

In the equation, ω is the angular frequency of the applied signal. Applied signal was carried out with frequency range of 20 Hz to 300 kHz. Bode plot of the real impedance versus frequency is shown in Figure 2. From the bode plot, it can be seen that the difference in electrical resistance of corroded and non-corroded specimens was captured and particularly that of the interface between the rebar and cement paste, where corrosion products are present.

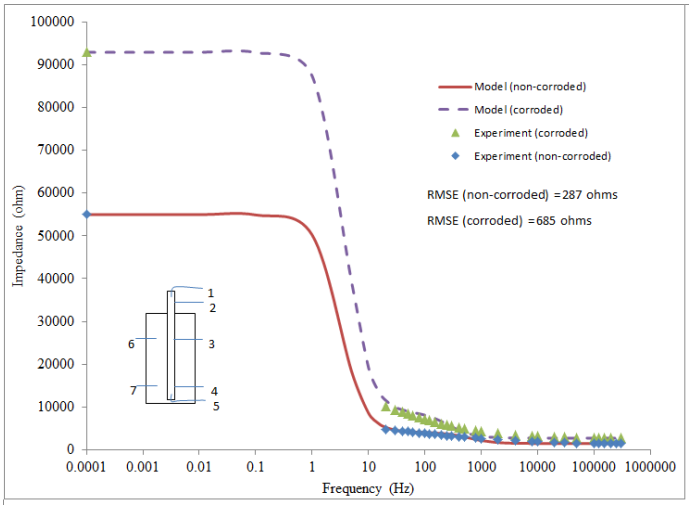


Figure 2 – Impedance vs Frequency

## 5. Conclusion

In conclusion, the analysis of piezoresistivity properties at the interface level could determine the difference in the electrical resistance and capacitance of interfaces between cement paste and corroded rebar, and cement paste and non-corroded rebar. This electrical and relatively simple test method could be effective in determining the presence of corrosion at the steel-cement interface.

## 6. Acknowledge

This study was supported by Texas Hurricane Center for Innovative Technologies (THC-IT) with funding from DOE/NETL/RPSEA (Project No. 10121-4501-01).

## 7. References

[1] H. G. Wheat, Smart Coatings for Corrosion Detection-A Review of Recent Advances, ISOPE, 2012
[2] Vipulanandan, C. and Prashanth, P., "Impedance Spectroscopy Characterization of a Piezoresistive Structural Polymer Composite Bulk Sensor," Journal of Testing and Evaluation, Vol. 41, No. 6, 2013, pp. 898–904
[3] Corrosion Costs and Preventive Strategies in the United States, NACE International