Characterization of Smart Polymer-Carbon Fiber Reinforcement Composite Using Impedance Spectroscopy

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Abstract: In this study, the behavior of a piezoresistive polyester polymer composite as a sensing coating was investigated. Impedance Spectroscopy (IS) was used to quantify the interface between the carbon fiber polymer strands (CFPS) and the polymer concrete. The electrical characteristics were estimated using the two-probe contact concept and different probe combinations measurements.

1. Introduction: Polymeric composites have been used efficiently to rehabilitate civil infrastructures. Furthermore, developing polymer-based composites to be used as a self-monitoring coating is an interesting trend towards assessing the quality of the host material and its interface with the interacting element. Accordingly, there is an increasing interest in the use of engineered materials capable of sensing the change of behavior of material elements under various loading and different environmental conditions. Polymer has many qualifying properties such as rapid setting, high strength-to-density ratio and its resistance to corrosion. The addition of conductive fillers such as carbon fibers enables its piezoresistive behavior and enhances as well its mechanical performance. Besides, the use of Carbon Polymer Composite as substitute reinforcement to steel is becoming popular due to its outstanding features such as high strength, lightweight, good durability, and resistance to corrosion and to aggressive environments. .

2. Objective: In this study, the objective of this study was to develop a self-sensing coating capable of identifying and monitoring the interface performance with the embedded material.

3. Materials and Methods: Based on the investigation on the performance and the piezoresistivity, in this study, the polyester resin was used by content of 25 % by weight of sand, the conductive filler content was 0.3 % by weight of resin. Cobalt napthenate (0.2 wt. % of resin) was added as promoter and methyl ethyl ketone peroxide (2 wt. % of resin) was used as initiator. After well mixing of the solution, the conductive fillers were slowly introduced and dispersed then mixed furthermore with addition of well graded sand to gain a uniform mix. Circular disk specimens (4 in x ½ in) equipped with contact wires embedded into the prepared molds.

4. Modeling of the piezoresistive behavior: The impedance (Z) between the two contact points on a specimen was measured during the test. The resistivity (ρ) is related to the resistance as follows:

$$\rho = R\frac{A}{L} \tag{1}$$

Where: A=cross-sectional area, and L=distance between the electrode contacts.
The total impedance of the equivalent circuit is given by (Vipulanandan and Prashanth, 2013) to extract the bulk and contact resistances (R_b, R_c) and the contact capacitance C_c (Eq. 2).

$$\boldsymbol{Z} = \boldsymbol{R_b} + \frac{2R_c}{1+\omega^2 R_c^2 C_c^2} - \boldsymbol{J}\frac{2\omega R_c^2 C_c}{1+\omega^2 R_c^2 C_c^2} \tag{2}$$

5. Results and Analysis: Figure 1 shows that higher impedance (Z_M) is meaured in the material compared to the interface impedance measured for all the inerface combinations. Sensing the interface change is also represented in figure (2).

6. Conclusion: In this study, the piezoresistivity of the polymer concrete coating was investigated. When the applied load was changed from 0 to 10 kN, the interface real impedance change, measured at 300 kHz, increased to 14%, showing the piezoresistivity of the smart polymer concrete coating.

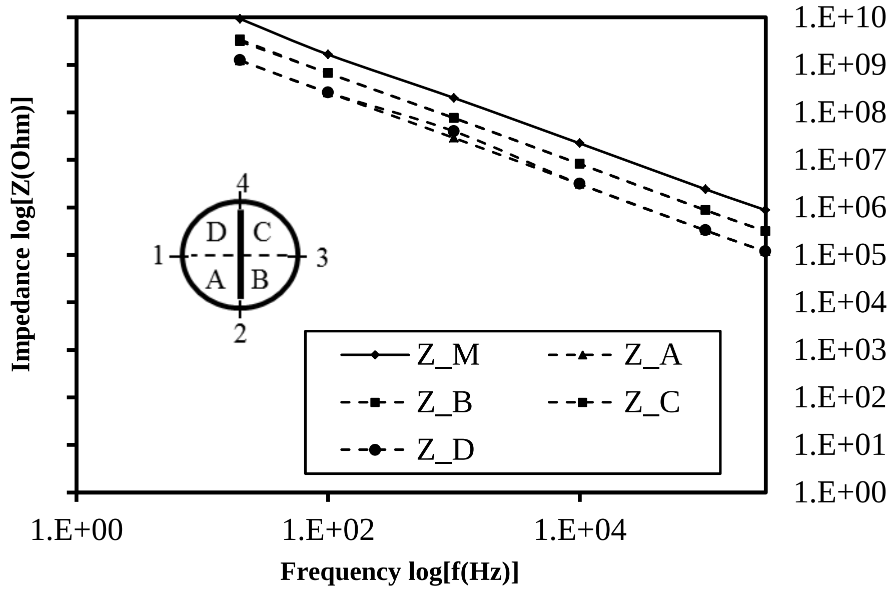

Figure 4. Impedance variation with frequency.

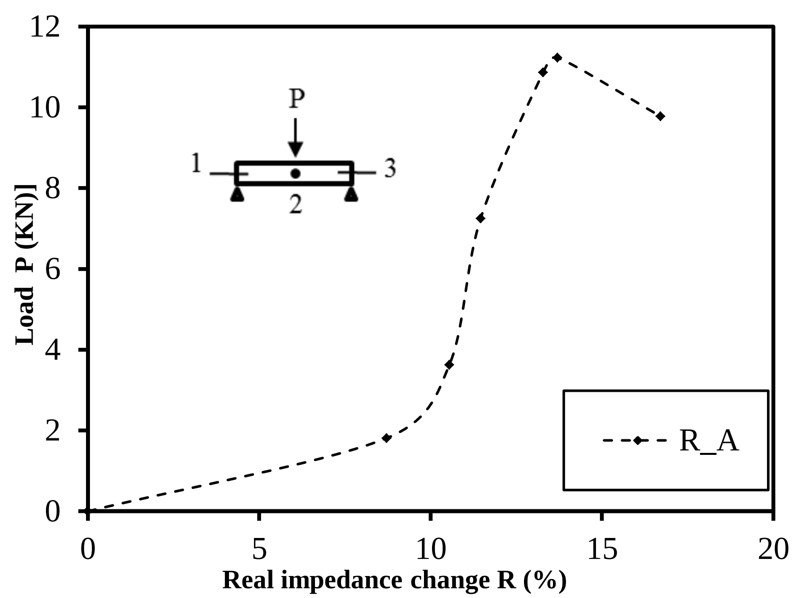

Figure 5. Real impedance change due to applied bending load [f=300 kHz].

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8. References:

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