Interface Characterization of Embedded Carbon Fiber Reinforced Polymer Strands in Sensing Cement

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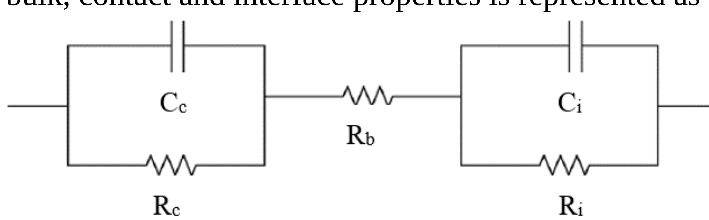
Abstract: In this study, the behavior of embedded fiber reinforced polymer strands in sensing cement was investigated. Impedance Spectroscopy (IS) was used to characterize the interface between the carbon fiber polymer strands (CFRPS) and the cement. Direct tension and bending tests were carried out to monitor the interface change under loading conditions.

1. Introduction: The increasing use of CFRPS as embedded rebars in different application such as reinforced concrete structures has been supported by their durability. They were used in the bridge construction (e.g. Floodway Bridge, Manitoba, Canada) as well as for structural strengthening (e.g. Bridge Cantilever Old Florida Keys Bridge, USA). However, the high durability of CFRPS has been defined only with regard to that of steel rebars that have the major concern of corrosion. Nevertheless, the durability of CFRP strands is a not well defined subject; it is more complex than corrosion of steel because their degradation depends on resin and fibers and on the interface bond behavior.

2. Objective: The objective of this study was to develop sensing materials for interface study and damage detection and monitoring the performance of the CFRPS- Cement interface under tension and bending loading conditions.

3. Materials and Methods: In this study, class-H hydraulic cement based on Portland cement-clinker and calcium sulfate was used to produce the cement composite materials. The water-to-cement weight ratio of 0.3 was adapted. A conductive filler was added by ratio 0.03 % (by weight of cement) to produce the sensing cement composite material. For the direct tension and bending tests, the conventional instrumentations consisted of (a) a load cell with capacity of 10 kip was used to measure the load; (b) a digital dial indicator was used to measure the deflection of the specimen. The specimens were equipped with embedded wires for IS measurements using E4980AL Precision LCR Meter.

4. Modeling of the interface: The equivalent circuit adapted to model the IS experimental measurements for the bulk, contact and interface properties is represented as follows:



(Case A)

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

Where:

ω = angular frequency, R_b= Bulk electrical resistance, R_c= Contact electrical resistance, C_c= Contact electrical capacitance, R_i= Interface electrical resistance, and C_i= Interface electrical capacitance.

$R_i C_i$ = Interface electrical property index.

5. Results and Analysis: The electrical interface property RiCi corresponding to the most damaged zone of the beam started to change gradually during the loading. A higher interface property change was recorded for the severely damaged area. The start of the crack propagation was observed through the shift in the interface change ratio at 60% of the ultimate load as shown in figure 4.

6. Conclusion: Based on the analyses of the experimental results, the interface electrical property index was used to characterize for the CFRPS- Cement composite interface under tension and bending loading conditions.

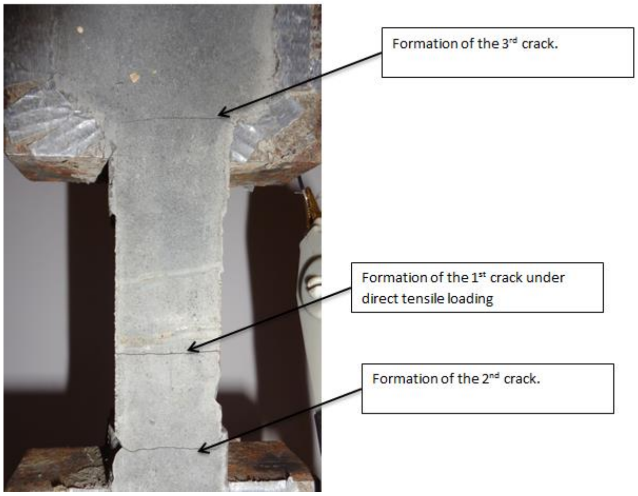


Figure 1. Direct tension test setup

Figure 2. Bending test setup

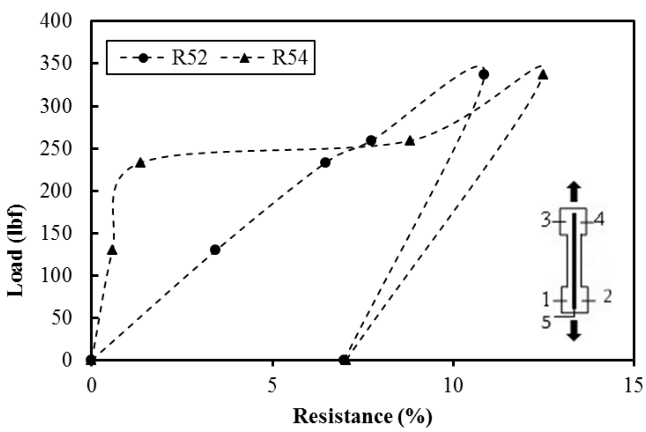


Figure 3. Resistance change under tension loading.

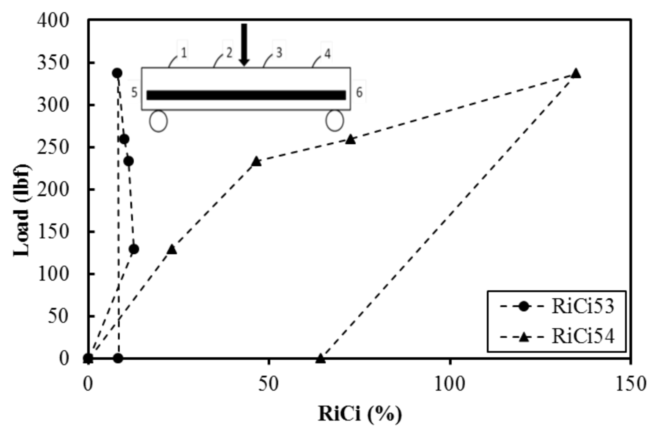


Figure 4. Interface property change under bending loading.

7. Acknowledgements: This study was supported by the Center for Innovative Grouting Materials and Technology (CIGMAT), University of Houston, Houston, Texas.

8. References:

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[2] American Concrete Institute. Committee 440. 2012. "Guide Test Methods for Fiber-Reinforced Polymers (FRPs) for Reinforcing or Strengthening Concrete Structures". American Concrete Institute.