Polymeric Piezoresistive Structural Sensors (PRSS-CIGMAT (P)) To Detect Small Pressures during Hurricane Winds

S. Pakeetharan 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, Texas 77204-4003
Email: spakeetharan@uh.edu, cvipulanandan@uh.edu Phone: (713) 743-4278

Abstract: Sensing of small changes in pressures is an important requirement for the sensors used in hurricane to monitor the wind pressures. A polymeric piezoresistive structural sensor (PRSS-CIGMAT (P)), a specially designed configuration, was studied to investigate the sensitivity to applied small pressures. The sensor was piezoresistive and it detected small pressures as low as 0.8 kPa (0.1 psi) with a maximum of change in resistivity of 0.5%.

1. Introduction

When a structure is exposed to wind, the surface areas of it are subjected to varying pressures that are continuously changing. During a hurricane, many of the offshore, coastal and onshore structures are affected by the wind and wave loading. Civil engineering structures are monitored during such events to study the effect of different intensity loadings. Since the pressure applied by hurricane wind on structures are small, the sensors should be made highly sensitive to detect it. Development and characterization of Polymeric Piezoresistive Structural Sensors, PRSS-CIGMAT (P), have been studied in the CIGMAT laboratory, University of Houston. As reported by Prashanth and Vipulanandan (2010), piezoresistive characteristics of a circular thin disk made with Fiber Reinforced Polymer Concrete (FRPC) aided in sensing small pressure (5.4 psi). In the current study, possibility of sensing even smaller pressures by piezoresistivity of polymeric composite material was investigated.

2. Objectives

Objective of this study was to investigate the sensitivity of shape of piezoresistive sensitivity of polymeric composites to detect small pressures.

3. Testing

A polymeric composite made of epoxy resin and aggregates was used in this study. An admixture in the amount of 2% by weight of composite was used in order to develop piezoresistivity. A stepped beam was casted and electrical wires were embedded in selected locations (denoted as ‘A’ to ‘G’ in the schematic diagram shown in Figure 1) while casting. Specimen was demolded after curing 1 day at 75˚F. Specimens were tested with two different support conditions. Firstly, the beam was simply supported and static uniformly distributed loads were applied in three different locations (at ‘R’, ‘S’ and ‘T’ as indicated in Figure 2a). Secondly, beam was inverted and clamped as shown in Figure 2b and loaded at two different locations ‘U’ and ‘V’. In both cases, electrical resistance was measured between different pairs of locations, before and while loading.

4. Results and Analysis

Percentage changes in resistance between selected pairs of conductive wires are summarized in Table 1 for the case of applied stress of 31 kPa (4.5 psi). It was seen that in all cases (for all locations of measurement and all locations of loading), resistance showed a change from the respective initial value, but in varying degrees. This can be attributed partly to the difference in stress experienced by the considered region. In Figure 3, piezoresistive behavior of the beam is presented when loading was applied at ‘U’ while the other end was clamped (refer Figure 2b). It was observed that similar trend prevailed for resistivity in different locations with increasing stress. By knowing the stress distribution, a relationship between stress and resistivity was established. Current study focuses on finite element modeling of the beam and loading in order to get accurate stress distribution along the beam by which the piezoresistive behavior can be explained.

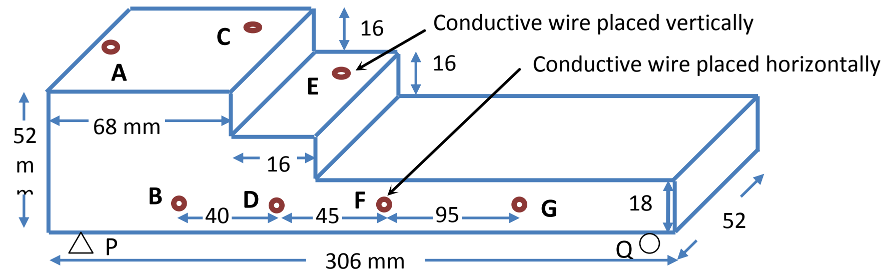

Figure 1: Schematic diagram of the stepped beam (dimensions are in mm)

Figure 2: Support conditions and loading locations, (a) simply supported (b) cantilevered

Table 1: Percentage change in resistance at applied stress of 31 kPa (4.5 psi)

Support condition	Loading location	% change in Resistance (for selected pairs of wires) A-C	B-D	D-F	F-G	E-D
Simply supported	R	0.6	-1.4	-1.0	-0.5	-8.6
	S	0.2	3.5	0.4	-0.2	1.2
	T	-0.5	-12.3	-14.0	-0.1	-15.8
Cantilevered	U	-0.2	-2.1	-0.7	-0.2	-2.0
	V	0.2	-1.0	0.7	-1.5	0.3

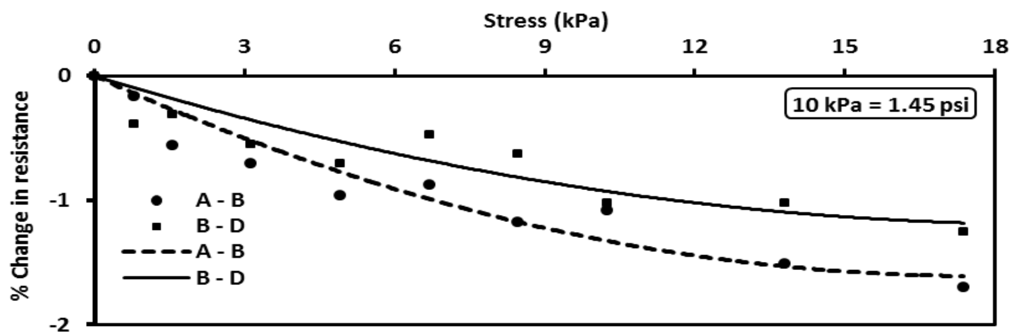

Figure 3: Piezoresistive behavior of the cantilevered beam

5. Conclusions

The studied PRSS-CIGMAT (P) sensor was piezoresistive and it detected small pressures as low as 0.8 kPa (~0.1 psi) with the maximum change in resistivity of 0.5%.

6. Acknowledgement

This study was supported by THC-IT with funding from the industries. Sponsors are not responsible for any of the findings.

7. Reference

Prashanth P. and Vipulanandan C., (2010). "Development and Characterization of PRSS for Hurricane Applications", *2010 THC Conference Proceedings*, http://www.egr.uh.edu/hurricane/events/files/Students/puvi.pdf (accessed July 13, 2011)