Designing Piezoresistive Self-sensor for Disaster Monitoring

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Abstract It is critical to monitor structures during disaster events to study the effect of different intensities of loadings. In this study, a piezoresistive structural material which is a self-sensor was a specially designed and was used to measure low pressures during disaster events such as hurricanes. Pressure of the order of 1.4 kPa was measureable with 0.5% change in resistivity.

1. Introduction

During a hurricane or any other storm, offshore, coastal and onshore structures are subjected to varying wind and wave loading. In order for rapid recovery after a major disaster, it is important to monitor the loading on critical structures during and after the event. As per ASCE 7-10, pressure exerted by a 50 m/s gust (lower limit for category 3 hurricane) at 10 m elevation is 1.28 kPa (0.186 psi). Since the pressure applied by the hurricane and storm wind on structures are relatively small, there is a need to develop sensors that are sensitive to detect low pressures. If self-sensing material can detect very small pressures it is ideal. 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 (37.2 kPa). In the current study, possibility of sensing lower pressures by piezoresistivity of polymeric composite material was investigated.

2. Objectives

Objective of this study was to design and test a stepped cantilever beam using self-sensing material to measure pressure of the order of 1.4 kPa (0.2 psi).

3. Material and Methods

A commercially available polymeric mix which included epoxy resin, hardener and aggregate was used in this study. Conductive filler (1% by weight of composite) was used to develop the piezoresistivity in the polymer composite. Compressive strength of this material was 65 MPa (9425 psi), higher than a typical construction material. In the stress range of 0 to 10 MPa, the piezoresistive coefficient $\prod_{111}$, which relates electrical resistivity to stress, varied from $1.62*10^{-3}$ MPa^{-1} to $1.31*10^{-3}$ MPa^{-1}.

Various shapes were investigated to study the effect in magnifying the stress to measure the changes in resistivity. This is important since the applied stresses (example wind stresses during a hurricane) are very small compared to the strength of the material. A cantilever beam with varying cross sections was selected for detailed analyses. The cross section of the beam was reduced in steps from the clamped end and hence referred to as ‘stepped beam’. The cantilever beam with three different sections was made. The selected depths were 35, 20 and 8 mm. The length and width of the beam were 240 mm (9.5 in) and 52 mm (2 in) respectively. Monitoring wires were embedded in selected locations (denoted as F, G and H in the schematic diagram shown in Figure 1) while casting. Density of the stepped beam was 2166 kg/m^3. Pulse velocity measurements were done on the specimen across the width at four different sections and across the length. Average velocity was 3650 m/s (11977 ft/s) and the results were within 2% which indicated that the cantilever beam had uniform properties.

4. Testing and Results

When a stress was applied at 190 mm from the clamped end (insert in Figure 1), a distributed stress was applied close to the location where the cross sections change while other parts of the specimen are carrying relatively lower stresses. The maximum stress was developed at the step changeover between F-G with a magnification of 425 times of applied stress. A comparison of piezoresistive response at different locations in the stepped beam with increasing loading is shown in Figure 1. The locations plotted represent unique parts of the beam where G-H is the thinnest part of the beam. The location F-G represents a section with changing cross section. Both of these locations had piezoresistive response for small stress levels (Figure 1). However the change in F-G was greater than that of G-H which was mainly due to the greater level of stress experienced at this location. At applied stress of 1.4 kPa the stepped beam showed about 0.5% change in resistance (F-G). Similarly at 7 kPa (~1 psi) a change of 0.8% was observed. Hence the stepped cantilever beam was effective in sensing low stress.

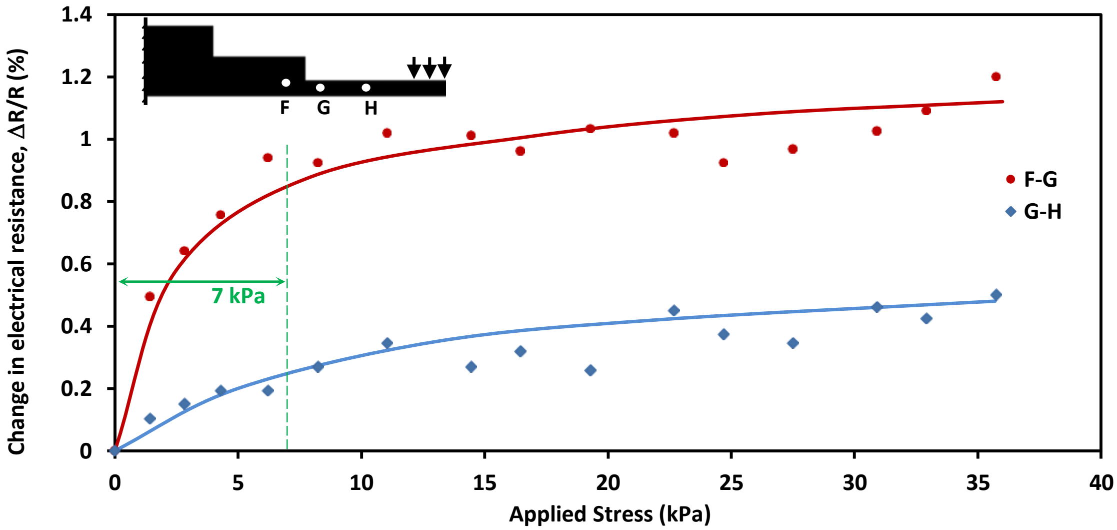

Figure 1: Comparison of piezoresistive response at different locations of stepped beam

5. Conclusions

Cantilever stepped beam made of the polymer composite was effective in detecting pressure of 1.4 kPa (0.2 psi). The internal stresses were magnified by 425 times the applied stresses so that the change in resistivity in the stepped beam was measurable.

6. Acknowledgement

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7. References

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