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New Applications of Fiber Optic Sensors for Structural Monitoring

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Introduction

The civil structures should be constructed and/or reinforced by materials that are significantly lighter, tougher and longer lasting, as FRP (Fiber Reinforced Polymer). Such materials is brittle, so they doesn't forewarn his failure, then it is important that such structures are continuously remotely monitored in order to communicate their performance under environmental and loading conditions. This allows engineers to check on a daily basis for a possible message of warning or of damage that could have a cost both in human live and in economical field. This paper describes an experimental program in order to assess the possibilities and the limits of fiber optic sensors (FOS) in structural testing and monitoring.

Experimental

The fibre optic sensor employed is designed around a FPI: Fabry-Pérot interferometer. The experimental program carried out consists in tests in both static and dynamic field, in order to achieve information relative to the performances of FPSs, compared to traditional strain gauges. Specimens made of steel and composite materials (CFRP) have been equipped by FOSs and electrical strain gauges (ESG). Tensile and flexural tests were carried out, in order to compare the two types of strain sensors. Dynamic tests too have been accomplished, with the aim to verify the possibilities and the limits of FOSs in the dynamic low frequency field. Finally, a beam of a RC bridge has been equipped with a FOS applied to a rebar, in order to check the capability of such sensors in monitoring the effect of temperature variations.

Results and Discussion

In figg. 1 and 2 we can see the data from different loading tensile cycles carried out on the steel plate and on the CFRP laminate, respectively.

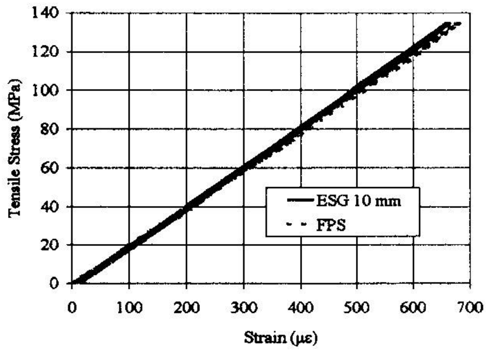

Fig. 1 Stress-strain curves for the steel plate

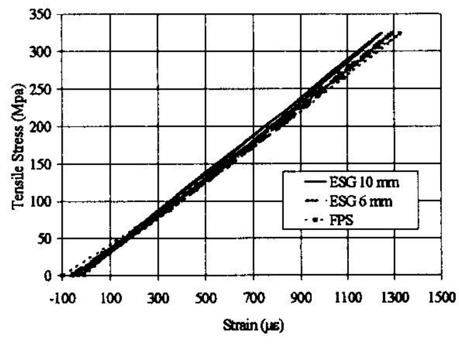

Fig. 2 Stress-strain curves for the CFRP laminate

Figures 3 and 4 reports the absolute value of the strain Vs the total applied load, in bending tests. The optic fiber device used in this experimental work wasn't designed for measures in a dynamic range, because of his low sampling rate (10 Hz). Nevertheless we carried out some tests in a low frequency range, which is very common in a wide range of civil structures. In Fig. 5 you can see the time domain signal of the FPS, compared to the one by the ESG. In the frequency domain (see Fig. 6) we can observe the same values given by the ESG, if we avoid the first frequency peak, which is affected by aliasing errors. When the natural frequency is lower than 5 Hz, equal to a half of the sampling rate of the device, the test becomes significant .

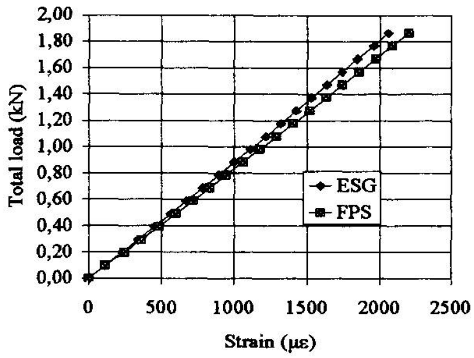

Fig. 3 Absolute value of the strain measured by FPS and ESG, when the FPS is in tension

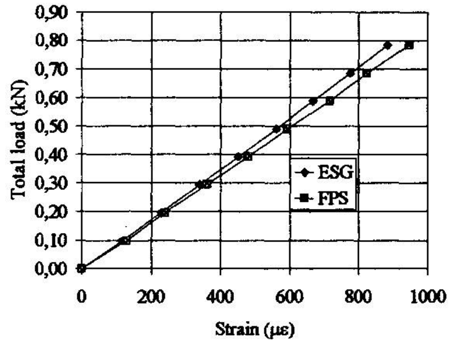

Fig. 4 Absolute value of the strain measured by FPS and ESG, when the FPS is in compression

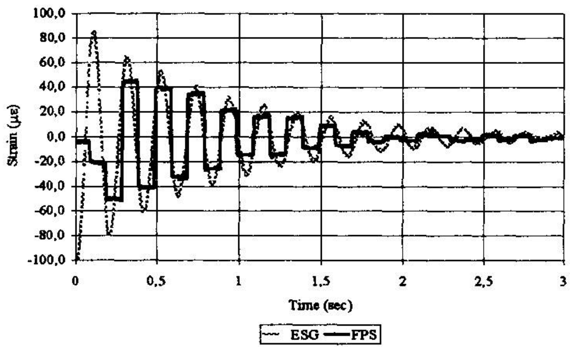

Fig. 5 Time domain signal of the FPS

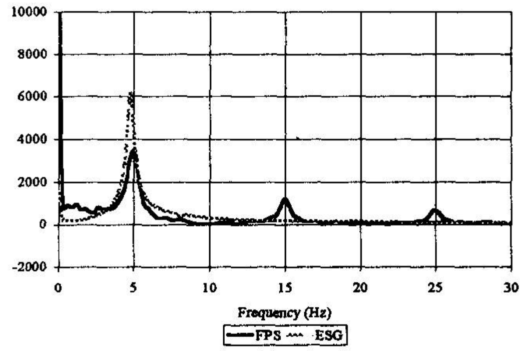

Fig. 6 Frequency domain signal of the FPS

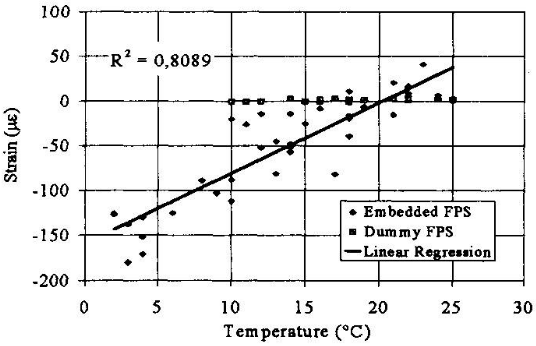

Fig. 7 Monitoring of a steel rebar of a bridge RC beam

Fig. 7 shows the results of the monitoring carried out on the bridge RC beam. The correlation between strain and temperature is linear with a good regression coefficient. The dummy FPS is not influenced by the temperature variations. The repeatability is very good. This is an important result, if we take into account that the device were disconnected and reconnected to the sensor at each reading. This is due to the very good coupling system, and is an important property of this type of sensor.

Conclusions

Fabry-Pérot Sensor (FPS) strain gauges has been tested in several conditions. Tension tests carried out on a steel specimen showed the agreement of the results between FPSs an traditional Electrical Strain Gauges (ESG). Identical tests on a CFRP specimen showed some differences between the two types of sensors, especially when 10 mm ESG are used. Also bending tests on a steel specimen showed good agreement between the two types of sensors, both in tension and in compression. Dynamic tests in a low frequency range confirm the possibility of using FPSs as vibration transducers, if an acquisition system with suitable sampling rate is used. As monitoring system, the fiber optic based system has demonstrated very good performance in terms of sensitivity to strain, repeatability of the readings and insensitivity of the sensor to thermal effects.