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Long term structural health monitoring by distributed fiber-optic sensing

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Structural health monitoring (SHM) systems allow to detect unusual structural behaviors that indicate a malfunction in the structure, which is an unhealthy structural condition. Depending on the complexity level of the SHM system, it can even perform the diagnosis and the prognosis steps, supplying the required information to carry out the most suitable actuation. While standard SHM systems are based on the use of point sensors (e.g., strain gauges, crackmeters, tiltmeters, etc.), there is an increasing interest towards the use of distributed optical fiber sensors, in which the whole structure is monitored by use of a single optical fiber. In particular, distributed optical fiber sensors based on stimulated Brillouin scattering (SBS) permit to detect the strain in a fully distributed manner, with a spatial resolution in the meter or submeter range, and a sensing length that can reach tens of km. These features, which have no performance equivalent among the traditional electronic sensors, are to be considered extremely valuable. When the sensors are opportunely installed on the most significant structural members, this system can lead to the comprehension of the real static behaviour of the structure rather than merely measuring the punctual strain level on one of its members. In addition, the sensor required by Brillouin technology is an inexpensive, telecom-grade optical fiber that shares most of the typical advantages of other fiber-optic sensors, such as high resistance to moisture and corrosion, immunity to electromagnetic fields and potential for long-term monitoring.

In this work, we report the result of a test campaign performed on a concrete bridge. In particular, the tests were performed by an portable prototype based on Brillouin Optical Time-Domain Analysis (BOTDA) [1,2]. This type of analysis makes use of a pulsed laser light and a frequency-shifted continuous-wave (CW) laser light, launched simultaneously at the two opposite ends of an optical fiber acting as the sensing element. By measuring the intensity of the transmitted CW light at various frequency shifts, the Brillouin frequency shift profile along the fiber is retrieved. As the Brillouin frequency shift is linearly dependent on strain (with a coefficient of about 500 MHz/%) and temperature (with a coefficient of about 1 MHz/°C), the instrument provides a measure of strain or temperature at each location along the fiber, with a spatial resolution determined by the duration of the optical pulse (we set a 1m-resolution in our tests). It is important to note that only a few examples of in-field demonstration of bridge monitoring by distributed sensors have been reported.

The optical fiber sensor was attached along one arch of the bridge using two types of adhesive for comparison purposes. The attached fiber was able to provide the strain distribution along the structure during the one-year test campaign and with a spatial resolution of one meter. A crack was revealed and correctly localized by the distributed sensor.

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