Bridge Sensing Using a Fiber Bragg Grating Quasi-Distributed Transducer: In-Field Results

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1. Introduction

Structural health and behavior monitoring has always been both a common concern and need in civil engineering. Several classic approaches have been given to this problem including the widely used strain gauges as well as the topographic measurements. These two techniques are almost always used to monitor the behavior of the structures whereas the health monitoring is accomplished by a simple periodic visual inspection. These approaches present serious problems that limit their practical use in real structures such as: lack of fiability, long-term drift (strain gauges), impossibility of full-time measurements (topographic measurements), or lack of thoroughness (visual inspection). Centering the discussion in the strain gauges, for being the most representative of the classical civil engineering monitoring methods, it must be said that due to their electric nature they are expose to both electromagnetic interference and corrosion. The latter greatly reduces their operating life time pushing it typically to less than one year after installation. That is why new ways of monitoring civil structures were looked for, and that is how photonic fiber sensing came up. Characteristics shared by all fiber sensors are their electromagnetic immunity for being manufactured using a dieletric material (silica glass), low weight, small size, and compatibility with construction materials [1,2]. As can be seen these inherent characteristics make them very suitable for their use in civil engineering structures. An example of a quasi-distributed transducer is presented in this communication. First the theoretical fundaments of the transducer and its behavior is explained, and an in-field experiment consisting on monitoring a bridge is described and its results reported.

2. TRANSDUCER

The transducers are based in Fiber Bragg Grating (FBG) technology [3]. A FBG is a periodic modulation of the index of refraction in the core of an optical fiber [4]. It has the property of reflecting a narrowband portion of this light's spectrum, whereas the rest of the light propagates through the fiber without suffering any distortion. The central wavelength at which the light is reflected is known as the Bragg wavelength. FBGs can be used as transducers because their Bragg wavelength changes with external parameters such as temperature, strain, etc. Nevertheless, it is necessary to discriminate if the change of wavelength is due to a variation of temperature, strain or both.

In order to accomplish this discrimination the transducers have two FBG. One is fixed to the transducer's body whereas the order is let loose. Thus, the first is affected by strain and temperature meanwhile the other only by temperature. The transducers have been made in methacrylate due to its compatibility with concrete. Prior to their installation in a real structure the transducers were calibrated an tested in several laboratory experiments.

3. FIELD INSTALLATION AND MEASURE

Once the developed sensors had been successfully tested in the laboratory, they were ready for field installation in a real civil structure. The chosen one was a bridge crossing the *Autovía del Cantábrico* at the kilometric point 48 of that highway, near *Cabezón de la Sal* (*Cantabria,*

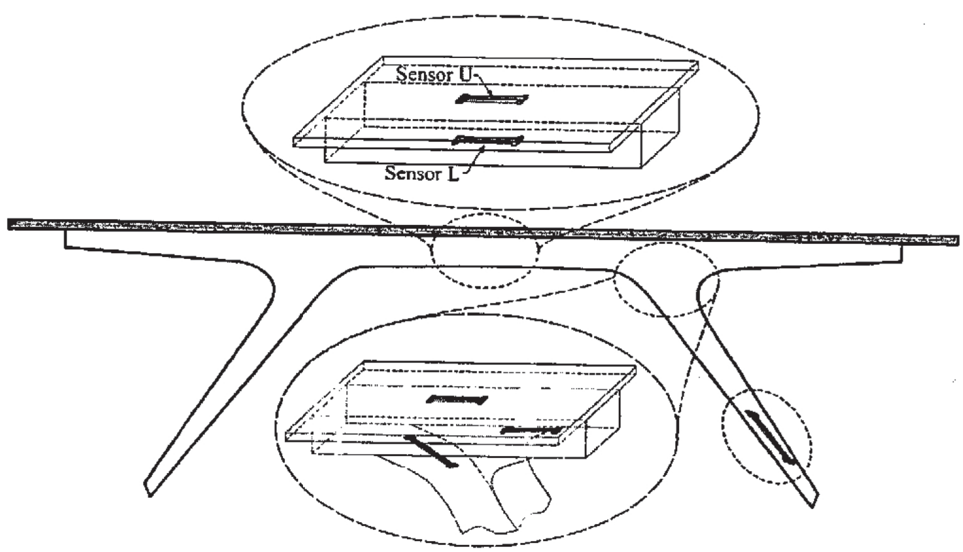

Fig. 1. Sensor distribution within the civil structure

Spain). Fig.1. is a diagram of the actual structure. The insets show the distribution of the installed sensors embedded the bridge. As can be seen the total number of transducers was six, being most of them in the upper side of the structure except for one which was installed centered in the base of one of the piles. All those sensors where installed in key points and were meant to measure different parameters, i.e. the sensors set in the middle of the bridge (named as sensors U and L) detect the total bond of it. From now on, the discussion will be focused on those two sensors for being the most representative of the behavior of the structure as a whole (the rest of the transducers detect mostly local effects in important points of it, which was of great interest for the designers of the structure). Once the sensors were installed the whole set of them behaved as a single quasi-distributed transducer with six sensing points.

It was during the load test of the bridge that the final corroboration of the system was made. Then a comparison between photonic sensors and traditional ones took place. In order to get the measurements a mobile lab was driven to the place. Fig.2. shows schematically the experimental setup used to measure the response of the quasi-distributed transducer during the load test. A FBG interrogation unit connected to the output port of the transducer is needed. A notebook computer was used to record the data extracted from the sensors during the test.

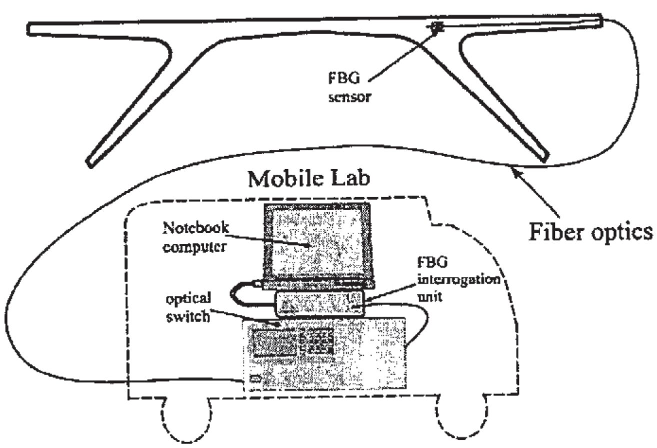

Fig.2. Experimental setup used to monitor the sensors during the load test

The load test consists on loading the bridge with several loaded trucks, each of which weighting an specific amount (50 tons in this particular case), placed in different positions along it. Each of the different dispositions of the trucks is called a "Hypothesis" (Figure 3).

In the present case there were three different "Hypothesis", shown in the upper insets of fig.4 and fig.5. The first one tries to load uniformly the bridge with four trucks placed on top of the piles in order to test them. The second one places these four trucks in the middle of the bridge in order to provoke the maximum bending of the structure. As third "Hypothesis" three of the loaded trucks were placed along one of the wings of the bridge so it would twist.

Figure 3. Photograph of the load test

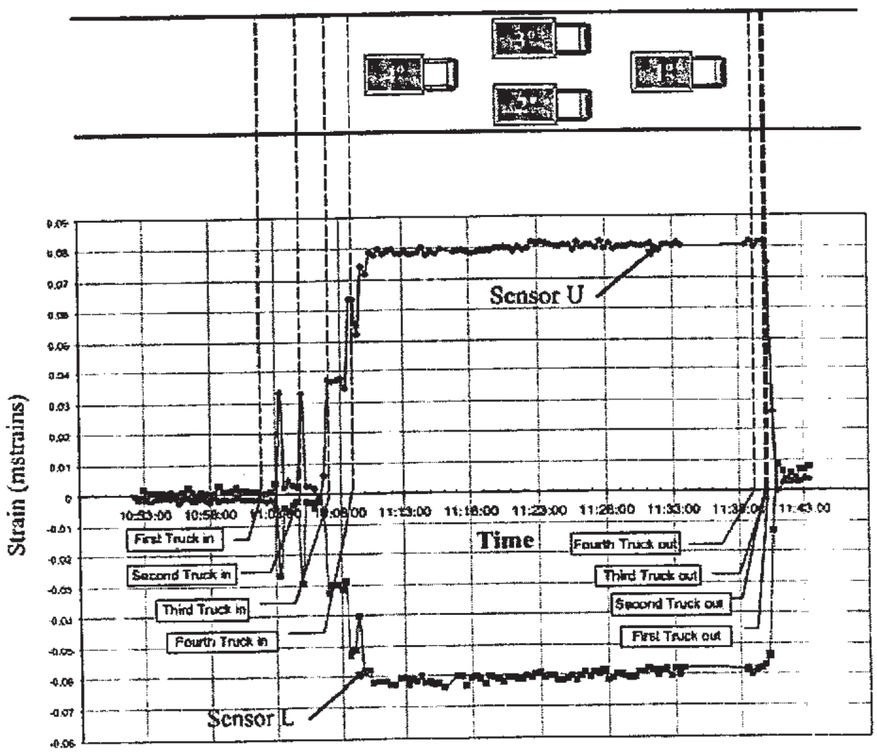

Fig.4. Recorded data from sensors U (upper graph) and L (lower graph) during the first "Hypothesis" of the load test.

Fig.4. shows the recorded data from the sensors U and L as well as the disposition of the trucks during the first of the "Hypothesis" and the arriving and leaving times of each of them. As can clearly be seen, the response of the sensors is as expected, that is, the one set in the upper part of the structure stretches (sensor U) and the one in the lower part compresses. Due to some asymmetry in the bridge, the response of the two sensors is not perfectly symmetric, being that of the U larger than the one from L. Not only is the stationary situation of the "Hypothesis" detected by the quasi-distributed transducer but every single event as well. This way each of the entrances of the trucks is registered as an increase/decrease in the stress of the sensors. This graphs also shows that, at the end of the loading, the structure did not recover completely and so the sensors did not return to their zero point. This fact was also shown by the traditional sensors (mechanical extensometers) installed to monitor the bridge. The rest of the data also correlates very well with those obtained from these traditional sensors.

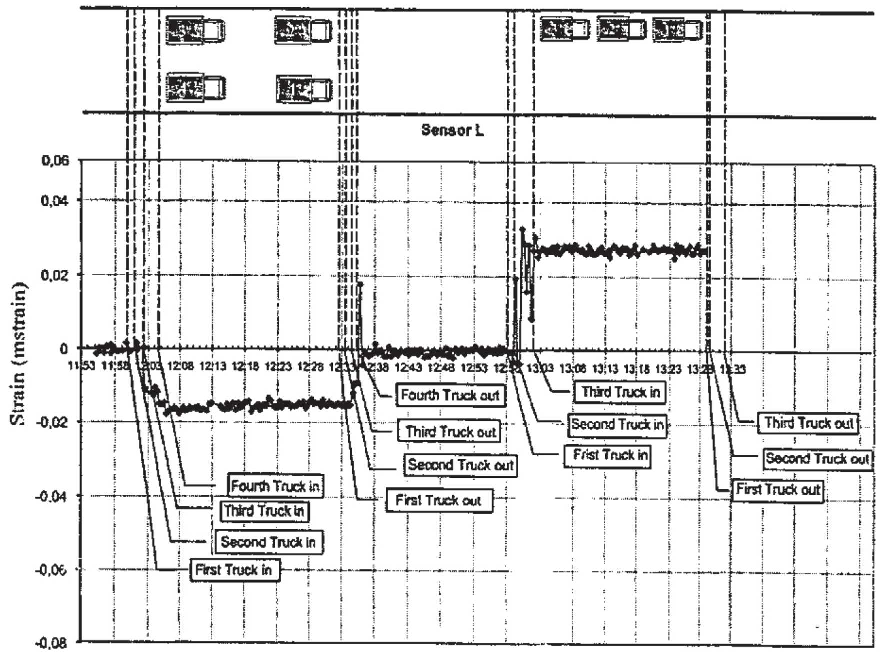

Fig.4. Data recorded from sensor L during hypothesis 2 and 3 of the load test.

Fig.11. Shows the response of the sensor L to the "Hypothesis" 2 and 3. As in the previous case this behavior is absolutely logical, let's see, when loading the piles the center of the bridge should be lifted and so the lower part of it should compress. In the same way in "Hypothesis" 3 when loading just a wing the structure should twist and then its lower part should be stretched. This behavior is perfectly reflected by sensor L as can be seen.

4. CONCLUSION

A final field installation of an embedded photonic quasi-distributed transducer is described in this paper. This transducer is based on in-fiber devices called Fiber Bragg Gratings whose inherent characteristics make them very suitable for civil engineering applications. The designed transducer is able to simultaneously monitor the deformation and temperature of their host structure in six different points. The transducer was installed in a bridge crossing a highway in the north of Spain. During the load test of this structure the recorded data from the photonic transducer were checked with those obtained from traditional ones and a very good agreement was found. This agreement validates the quasi-distributed transducer for its use in this application.

5. ACKNOWLEDGEMENTS

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