Preliminary Study on the Long-term Stability of Fiber-Optic Sensors

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Summary

Engineering structures such as bridges, dams or larger buildings are subjected to deterioration over time. Based on the requirement to ensure the structures' reliability and usability their performance and condition has to be monitored continuously or at least checked periodically. Adding to the range of available system fiber-optic sensors are becoming increasingly popular. In course of this paper the basic characteristics of fiber-optic sensors in permanently installed monitoring systems will be discussed including benefits over other sensor technologies. Since long-term stability is an important property for sensors applied within a permanent monitoring system a study was set up to look into the effects of vibration on the sensors' stability. The associated experimental set-up and test program will be discussed. Finally first results concerning the long-term stability and applicability of fiber-optic sensors in long-term monitoring systems will be presented.

Keywords: Monitoring system; fiber-optic sensor; endurance limit; vibration; laboratory experiment

1. Introduction

For several years now structural health monitoring (SHM) has become increasingly present in the engineering community. This development was on one hand caused by budgetary constraints which forced operators to consider life-cycle-costs and optimize their maintenance work according to the actual condition and reliability level of the structures and secondly rising risk awareness concerning possible bridge disaster. Both arguments pushed the development of new and the improvement of existing monitoring and sensor technologies.

Traditional design concepts are based on (a) experience of the engineer and (b) specifications indicated in current codes. The latter mainly include information about material properties, load models and further rulings about structural detailing in order to ensure sufficient safety, robustness and durability. Although material properties and load-deflection curves for various materials are rather well established and available in different software solutions, load models generally meet reality only on a restricted scale. Monitoring and suitable recording concepts allow the reduction of uncertainties associated with real material properties, actual loads and the development of structural parameters over time as well as the performance of new or adapted design concepts. Depending on the type of structure different critical construction phases or structural elements with corresponding structural properties can be determined and need to be addressed by the respective monitoring system. Apart from verifying various aspects of design, monitoring systems can be applied in order to minimize risks during construction as well as operation and even optimize rehabilitation and maintenance in case of a permanent monitoring solution.

Generally concepts for short-term monitoring as well as long-term permanent solutions have to be differentiated. Whereas for the former resolution, accuracy and even mobility are the decisive properties, the main characteristics of sensors in long-term-monitoring systems shift to

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repeatability, long-term stability and independence from environmental conditions. Fiber optic sensor (FOS) systems are ideally suited for both tasks since they provide high resolution and repeatability and show little aging effects. However the application of fiber-optic strain sensors within dynamically loaded reinforced concrete members raises questions regarding to durability of the entire set-up sensor-bond-concrete. In order to determine the long-term stability of FOS embedded in concrete under cyclic loading a serious of ongoing laboratory tests and numerical calculations have been initiated.

2. Design of experimental layout

Based on experience from previous projects the combination of a vibration prone steel beam and small concrete specimens was chosen for the layout of the tests, as shown in Fig. 1. The design of the experimental rig and the RC-specimens was governed by (a) the effort towards as little stiffness as possible in order to allow for large amplitudes and thus strains while (b) ensuring a concrete cover large enough to accommodate the fiber-optical sensor and (c) material properties which at least partly meet reality. Furthermore the geometry of the specimens together with the detailing of the test rig should ensure a full propagation of forces –both tension and compression – as well as bending moments between the vibrating steel beam and the RC-body.

3. Numerical simulations

In order to verify the design of the test set-up a pseudo-static non-linear calculation was performed. Fig. 1 (a) shows the modeling of the entire experimental rig which is loaded with deformation in two points near the supports. In Fig 1 (b,c) the connection between concrete specimens and steel beam as well as the resulting crack pattern, strain distribution and stresses in the reinforcement bars are shown, based on which the experiment was designed.

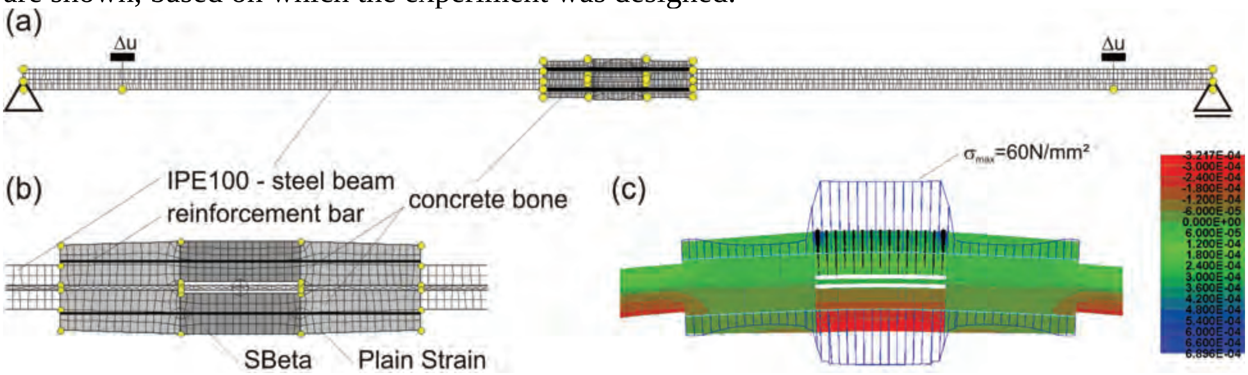

Fig. 1: Numerical verification of laboratory tests on a steel beam with FOS embedded in concrete bones – modelling and numerical results

4. First results

Testing of the first specimens instrumented with strain gages served for the optimization of the experimental set up and the testing procedure and verified the design of the test-rig. A series of tests including FOS will provide insight into the long-term stability of FOS monitoring systems and in consequence will essentially contribute to structural health monitoring considerations.