Effect of Concrete-Steel Interactions on the Performance of Emended Distributed Optical Fiber Sensor; Review

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Abstract

Distributed optical fiber sensor (OFS) is a cutting-edge technology that has been introduced to the construction industry as a structural health monitoring system for the structural assessment of existing and newly built structures. The OFS can be attached to the surface of the existing structures or embedded into the newly built structures. Furthermore, the bond stress resistance produces the composite action at the embedded reinforcement and the adjoining concrete interfaces. This study is developed to determine the effects of the interaction at the interfaces and their impact on the performance of the distributed OFS as a monitoring system of the structural health. The strain evolution will be obtained from the previous study and used with different perspectives compared to the original research. Therefore, monotonic loading was applied in terms of displacement control with roller supports to obtain the maximum strain profile of the reinforced concrete beam. The result obtained will be used to develop the relationship of the bond-slip and compare it with Model Code 2010 predicated bond-slip relationship. Therefore, the bond-slip relationship is significant concern to evaluate the impact of the concrete-to-steel interaction on the OFS performance.

Keywords

Distributed optical fiber sensors • Strain evolution • Concrete-steel interactions • Monotonic loading • Structural health monitoring

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1 Introduction

The distributed optical fiber sensor (OFS) is an innovative tool that is used in many industries around the globe. It has been introduced to the construction business as a mean of observation to the structure's health along its life span. It could be imbedded on the newly constructed structure or planted on the existing one. Furthermore, OFSs have the ability to monitor the structural element throughout the entire optical fiber in a fully distributed way (Barrias et al. 2016). By evaluating it in terms of cost, it was found to be low in comparison with the traditional method and more efficient as well. It offers a wide range of applications in the construction industry, such as continuous monitoring of existing or newly built structures (Bado et al. 2020; Barrias et al. 2016). On the other hand, the conventional structural health monitoring method relies heavily on visual inspections carried out by trained engineers (Barrias et al. 2016; Davis et al. 2016).

The OFS is a non-destructive tool that has been used to monitor the serviceability condition of structures to provide proper risk management in order to prevent structural failures through regular maintenance updates. It can be entrenched into the newly built structures or attached to the surface of the existing structures (López-Higuera et al. 2011). Thus, the strain record will commence as soon the temperature is transferred to the fiber and the scattered signal is modulated by strain and temperature (Barrias et al. 2016). Actually, both the strain profile and the interaction between the concrete and steel could be achieved through the embedded optical fiber. The interaction at the interfaces of the embedded reinforcement and surrounded concrete for any sort of structural element is known as the bond zone. This bond zone experiences multi-complex stress actions in the forms of secondary splitting microcracks, local concrete crushing for the member, and shear crack for the concrete member in front of the ribs (Jakubovskis and Kaklauskas 2019).

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The distributed OFS relies on bonding at the interfaces between the OFS properties and the surrounding materials to monitor the strain distribution (Ansari and Libo 1998). The extracted strain profile that was generated by the optical fiber, provides strain measurement of the structural materials to determine the composite action between the concrete and steel. However, the output of the strain profile is not fit to be used as representative of strains induced directly as an input to evaluate the bond stress (Ansari and Libo 1998; Bado et al. 2021). The strain field transferred of the structural material is affected by the glass core, glass cladding, and protective silicone coating. On the other hand, the bond stress resistance produces the composite action at the interfaces between the surrounded concrete and the embedded reinforcement (Kankam 1997). At those interfaces, the total bond resistance of the element consists of both bearing and friction resistance (Murcia-Delso and Benson Shing 2015).

The bond-slip relationship models were developed for monotonic and cyclic loading and used in the finite element analysis to simulate concrete member's bond stress at the interfaces of the deformed bars and the surrounding concrete in order to evaluate their ultimate structural capacity at the required period. Some researchers (Eligehausen et al. 1982) have carried out an extensive experimental investigation (Eligehausen et al. 1982) to develop a model for the bond-slip relationship. On the other hand, another bond-slip model, known as Model 2010, was developed by Beverly (2010) based on extensive research and experimental work. Few researchers (Bado et al. 2021; Kaklauskas et al. 2019) have used the stress approach and Model Code 2010 to validate their experimental findings. Therefore, bond-slip models and stress approaches play a significant role in evaluating the performance of the distributed OFS. In this study, the effect of the steel-to-concrete interaction on the performance of OFS is assessed based on the extracted strain profile through an embedded OFS.

2 Proposed Methodology

The goal of this research is to find out how steel–concrete interactions affect the performance of emended distributed OFSs. The data for this study will be gathered through literature reviews of published studies, and the information gathered will be analyzed from other angles than the original study. The OFS's strain profile will be the major source of data collection. The bond-slip relationship could be determined using numerical analysis using the reinforced concrete (RC) beam strain profile extracted and obtained from the previous investigation by distributed OFS. The research methods and approaches employed to reach the study work's goal will be highlighted in this part (Kaklauskas et al. 2019).

The research approach framework for this study as stated by the authors starts by a literature review. The literature review is important since the data gathering will be done through previous studies. The features and uses of the OFS in the construction industry will be examined throughout the literature review. On the other side, past investigations will be used to illustrate the extracted strain profile and numerical formulation of the bond-slip relationship. The focus of this research will be on the bond-slip behavior of RC beams under monotonic load utilizing OFSs, so far to investigate the effect of steel–concrete interactions on the performance of emended distributed OFSs along the structural member. The relationship between the structural behavior of both bond and slip between the concrete element and steel reinforcement bars for the structural element will be compared to the measure of Standard Code 2010 based for slip-bond relationship. OFSs will extract a strain profile, which will be used to construct the bond-slip relationship (Bado et al. 2021).

The strain evolution along the RC beam as derived by the OFS and the Model Code 2010 predicated slip-bond relationship will be the initial step of data gathering in this investigation. The structural behavior of the relationship between bond and slip that were specified for structural elements composing the concrete member will be calculated using the approach of strain evolution to examine the reinforcement steel bar interaction with a concrete element. The prior method that was reported will be used to develop the strain-bond-slip relationship (Bado et al. 2021; Kaklauskas et al. 2019).

2.1 The Geometry of RC Beam

The specimen is made up of RC beams with embedded OFSs and two supports as described by Berrocal et al. (2021). The OFS was implanted into the RC beam and fastened to the reinforcement bar, with a cross-section of 100 mm × 150 mm and a beam span of 800 mm from the center of the supports. The goal of attaching the OFS to the steel bar is to see how steel–concrete interactions affect the performance of the modified distributed OFS. The retrieved strain profile will also be used to build the bond-slip curve as a source of the element strain, due to the OFS was linked to the steel bar (Barrias et al. 2018).

2.2 Test Setup

The specimen that was intended to be tested consists of RC beams with embedded OFSs, hydraulic jack, load cell, and 80 mm × 100 mm loading plate as shown in a study by Berrocal et al. (2021). The beam was subjected to a point load at the mid-span, and roller support was used to obtain the maximum strain profile using a hydraulic jack. Displacement control for the tested member was applied at the mid-span upon closed-loop feedback system at every 0.5 mm/min displacement measure rate as monotonic loading for the testing sample along the period.

3 Conclusions

This study will be mainly focused on the influence of the steel–concrete interaction on the OFS. The data collection for the study will be obtained from previously existing published articles and other materials with different perspectives. The extracted strain profile or strain evolution will be used to develop the slip-bond relationship and relate it with the Code Model 2010 predicated slip-bond relationship. Based on the comparison of the developed slip-bond relationship and Code Model 2010 predicated slip-bond relationship, which is affecting concrete and steel interactions of the structural member on the emended distributed OFSs performance in the assessed member. Therefore, the slip-bond relation is significant concern to evaluate the impact of the steel-to-concrete interaction on the performance of the OFS.

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