STRAIN-VISION – Strain Monitoring on Pre-Stressed CFRP Laminates for Reinforcement of Concrete Members using Computer Vision

Summary

Currently, strengthening reinforced concrete (RC) members with FRP solutions is a widespread technique. The success of this in increasing the strength and/or in controlling the deformation of structural members has been recognized worldwide, and most relevant aspects have been thoroughly studied and published. For large span beams and slabs, the method is much more effective if prestressed FRP laminates are adopted. Therefore, onsite measurements of the applied strain level, as well as of the evolution of the latter with time due to prestress losses, are mandatory to ensure a correct operation and to monitor the time-dependant behavior. Presently, the strain applied is assessed only indirectly, through load control when prestress is applied, and the losses are not conducted. In this context, the development of a non-destructive cost-effective method, allowing measuring the laminates strain during the strengthening operation as well as during periodic inspections later on, would represent a major added value for this already widespread technique.

Figure 1. CFRP laminates for strengthening RC structures.

Computer vision emerged in the 1960s at universities that took the first steps in the field of artificial intelligence. Despite, potentially, having a vast field of application, it has only recently begun to be used in the evaluation of existing structures in reinforced concrete. The CERIS Research Group, which integrates the present application, was a pioneer in this field, having developed in the last 15 years' scientific research in this area, resulting in several applications in the field of inspection and monitoring of structures, particularly reinforced concrete or prestressed concrete, through image processing. More specifically, methods have been developed to: (i) automatically detect and characterize cracks in concrete structures, based on image processing; (ii) evaluate and map anomalies and repairs on concrete surfaces, based on multispectral image analysis; (iii) measure displacements and deformations in load tests on buildings, bridges and dams, as well as laboratory tests, based on photogrammetry. Nowadays, compute vision approaches for Structural Health Monitoring are one of the research focuses.

The present project, here referred to as the STRAIN-VISION, has the ultimate objective of, based on the CFRP laminating system (patented by S&P) and the know-how of the CERIS team in computer vision, in particular the methods themselves developed (and validated in laboratory and in real structures, in most cases bridges), to develop a new system, consisting of three main modules (Figure 2): (i) development of a new product, the high precision CFRP laminate - hpsm-CFRP (Figure 3); (ii) equipment adapted to the needs of the system, considering different digital cameras set-ups for a large range of scenarios; (iii) a new process of monitoring the strain/tension state of the CFRP laminates, either during the execution of the reinforcement, including the prestressing application phase, or during the subsequent period in service, based on deep learning algorithm for computer vision. This new system of reinforcement of reinforced concrete members with pre-stressed CFRP laminates with deformation monitoring, and consequent estimation of installed tension state, results into a very significant increase in safety and reliability, thus representing a huge plus value at an absolutely marginal cost.

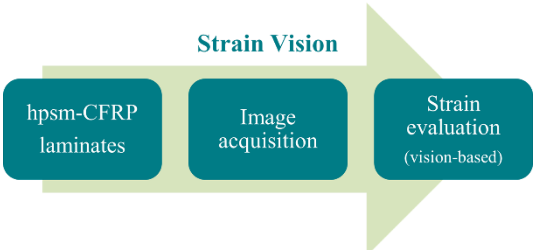

Figure 2. Strain Vision main modulus.

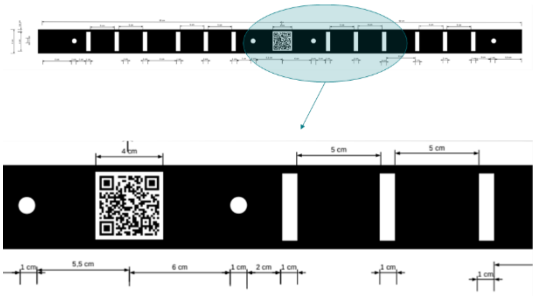

Figure 3. New hpsm-CFRP laminates for calibration and validation.

Project Reference

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Leading Institution

S&P – Clever Reinforcement iberica - Materiais de Construção Lda (Portugal)

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CERIS

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Project Website

www.sp-reinforcement.pt/pt-PT/noticias/strain-vision-projecto-de-investigacao-cofinanciado-pelo-compete-2020

The project is organized in the following six tasks: (1) technical specifications, to define the required precision, the characteristics of the targets/patterns, and the spacing of the latter, depending on the prestress magnitude, and on the equipment adopted for image acquisition; (2) system development, where the components of the systems are developed, product, process and equipment. In this activity is also important the development of graphic outputs and alerts system; (3) calibration tests, where the various system components, such as CFRP-hpsm laminates, computer vision processing, acquisition equipment, outputs and alerts system, should be calibrated (Figures 4); (4) validation tests, to testing the system and evaluating its behavior in several real scenarios, with different environmental conditions; (5) promotion and dissemination of results through the publication of articles in journals (jointly with S&P and IST), oral presentation at conferences, and participation in trade fairs; (6) project management, guaranteeing the fulfillment of the established goals, according to the defined timeline, and ensuring the delivery of the expected deliverables.

Figure 4. Calibration tests.

The results obtained suggest that deep learning provides a stable and accurate approach to reach a high confidence method, allowed to measure the evolution of the strain level on the hpsm-CFRP laminate during the pre-stress application. An RMSE (Root Mean Square Error) of 0.060‰ was achieved in calibration tests (Figures 5). Further, it should be highlighted that the deep learning approach can evaluate the strain applied equally on images with and without noise.

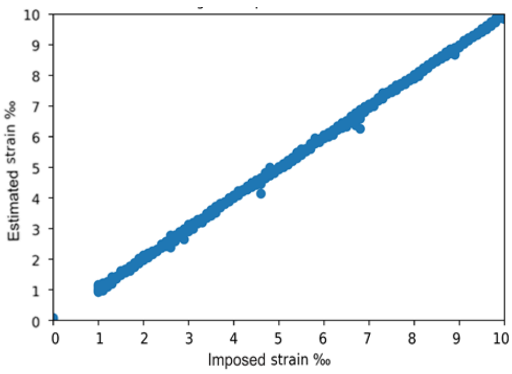

Figure 5. Strain imposed vs. strain measures of the calibration tests.

From the results achieved in the ongoing STRAIN-VISION project, the following conclusions can already be draw:

- The hpsm-CFRP laminates enables the detection of the coded patterns printed on images. The last version will the defined after the onsite validation of the proposed solutions.
- The image acquisition plays a key role in the systems. The acquisition of images with characteristics as close as possible to those used in the training process will allow more precision and accuracy measurements. The acquisition planning and the cameras used must be carried out in accordance with the pre-stress level to apply.
- The results achieved demonstrate that the algorithms propose and implemented allows to measure the strain level during the application of pre-stress in CFRP laminates, for strengthening reinforced concrete structures, with the required precision.