Zukunft Bau

# Abstract - Intelligent CFRP-patch – 01.08.2018

## Title

"Condition-monitoring of Steel-CFRP-joints using integrated fiber optical sensors"
("Intelligent CFRP-patch")

## Starting situation

A new approach for strengthening of steel structures is the adhesive bonding of carbon fiber reinforced plastics (CFRP). Despite the reinforcement effects as shown in the literature, there has previously been a lack of non-destructive monitoring and analysis methods to increase the acceptance and confidence in structural bonding and to generate new insights into the durability of the steel-CFRP-joints. Very thin fiber-optic sensors, integrated in the adhesive layer, can help to gain new insights into the behavior of the adhesive layer under complex environmental and mechanical conditions.

## Aim of the research project

The possibilities of using fiber optical sensors for condition monitoring of steel-CFRP-joints have been investigated in the project by using Fiber-Bragg-Grating-(FBG)-sensor technology and optical frequency domain reflectometry. For the investigations, FBG-sensors and distributed fiber sensors were integrated in the adhesive layer of steel-CFRP-joints and steel components with externally bonded CFRP lamella. In mechanical tests under defined loading conditions and tests involving temperature and moisture stresses, strains were measured, systematically analyzed and evaluated with integrated fiber optical sensors. The sensor data were validated with temperature sensors, load and displacement data from the testing machine as well as with electrical strain gauges, digital image correlation and the numerical simulation using finite element method. The embedding characteristics and failure mechanism of the joints were assessed by using x-ray computer tomography, light microscopy and puls-phase-thermography. In a simple field test a steel profile with bonded CFRP-lamella and in the adhesive integrated sensors was stored outside for 7 months and parallel sensor data was continuously recorded and analyzed.

## Conclusion

The investigations on the joints and steel components with bonded CFRP-lamella showed, that strain and strain distributions in fiber direction in the adhesive layer can be measured with high accuracy and high spatial resolution during mechanical and thermal loading of the joint systems. The measured strains in the adhesive layer were confirmed by electrical strain gauges and numerical simulations based on the Finite Element Method. In addition it was found under high mechanical loading of the joints and components, that the delamination of the adhesive layer from the steel surface at the edge of the joint can be detected by using fiber optical sensors. The delamination was confirmed quantitatively and qualitatively by using electrical strain gauges and puls-phase-thermography, respectively. The study demonstrate the potentials of fiber optic sensors for condition monitoring of strain in the adhesive layer of structural joints. The current strain state and damage due to the delamination in the joint can be determined. By knowing the mechanical performance of the construction the fiber optical measurement systems allows the identification of critical strain states and thereby the assessment of the load limits of the construction.

## Key data

Research Organisation:

(1) Materialforschungs- und -Prüfanstalt an der Bauhaus-Universität Weimar (MFPA), Coudraystraße 4/9, 99423 Weimar

(2) Fachgebiet Fertigungstechnik (IFT),Technische Universität Ilmenau, Gustav-Kirchhoff-Platz 2, 98693 Ilmenau

Researchers:

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Project partners:

Advanced Optics Solutions GmbH
FBGS Technologies GmbH
RSB Rudolstädter Systembau GmbH
Sika Technology AG
S&P Clever Reinforcement GmbH

Total costs: 212.078,54 € €

Share of federal subsidy: 139.613,04 €

Project duration: 24 months

## FIGURES:

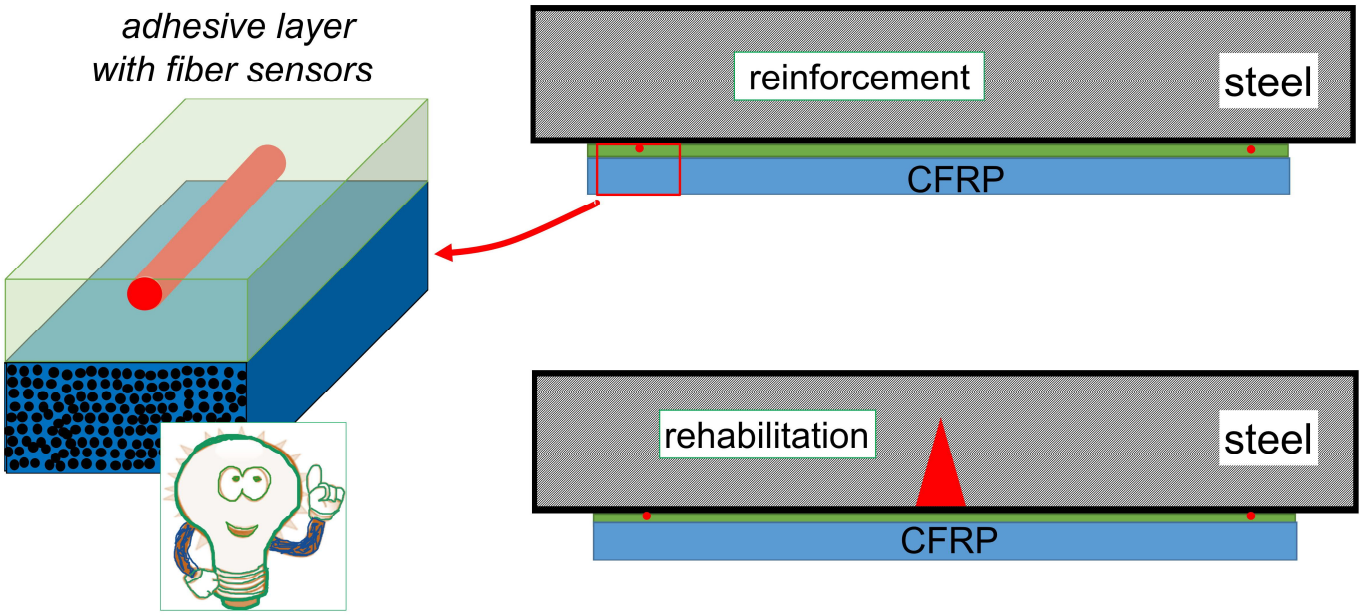


Figure1: Scheme of the innovative approach in the project „intelligent CFRP-patch “

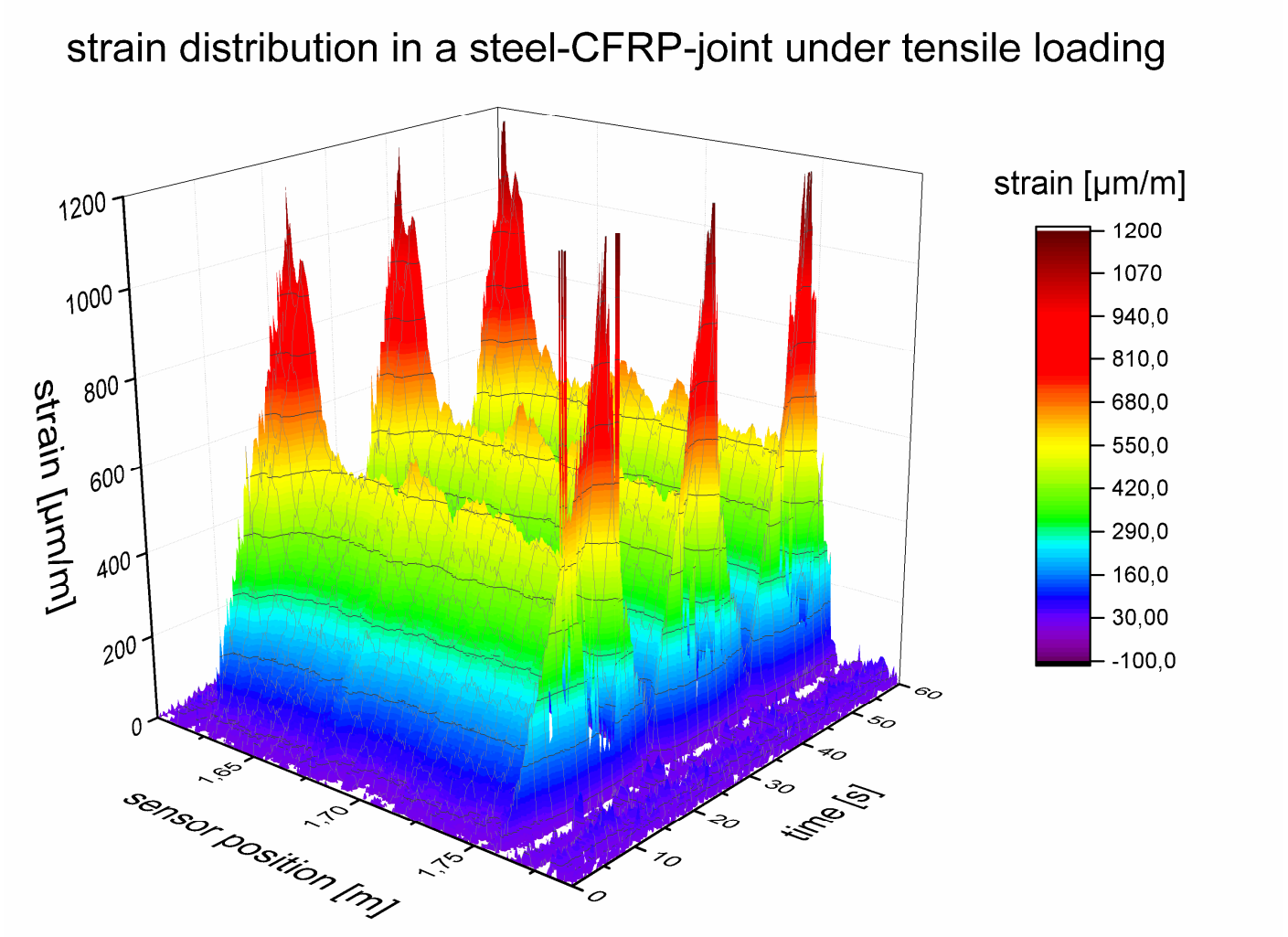


Figure 2: Strain distribution in a steel-CFRP-joints with integrated distributed fiber sensor under cyclic tensile loading

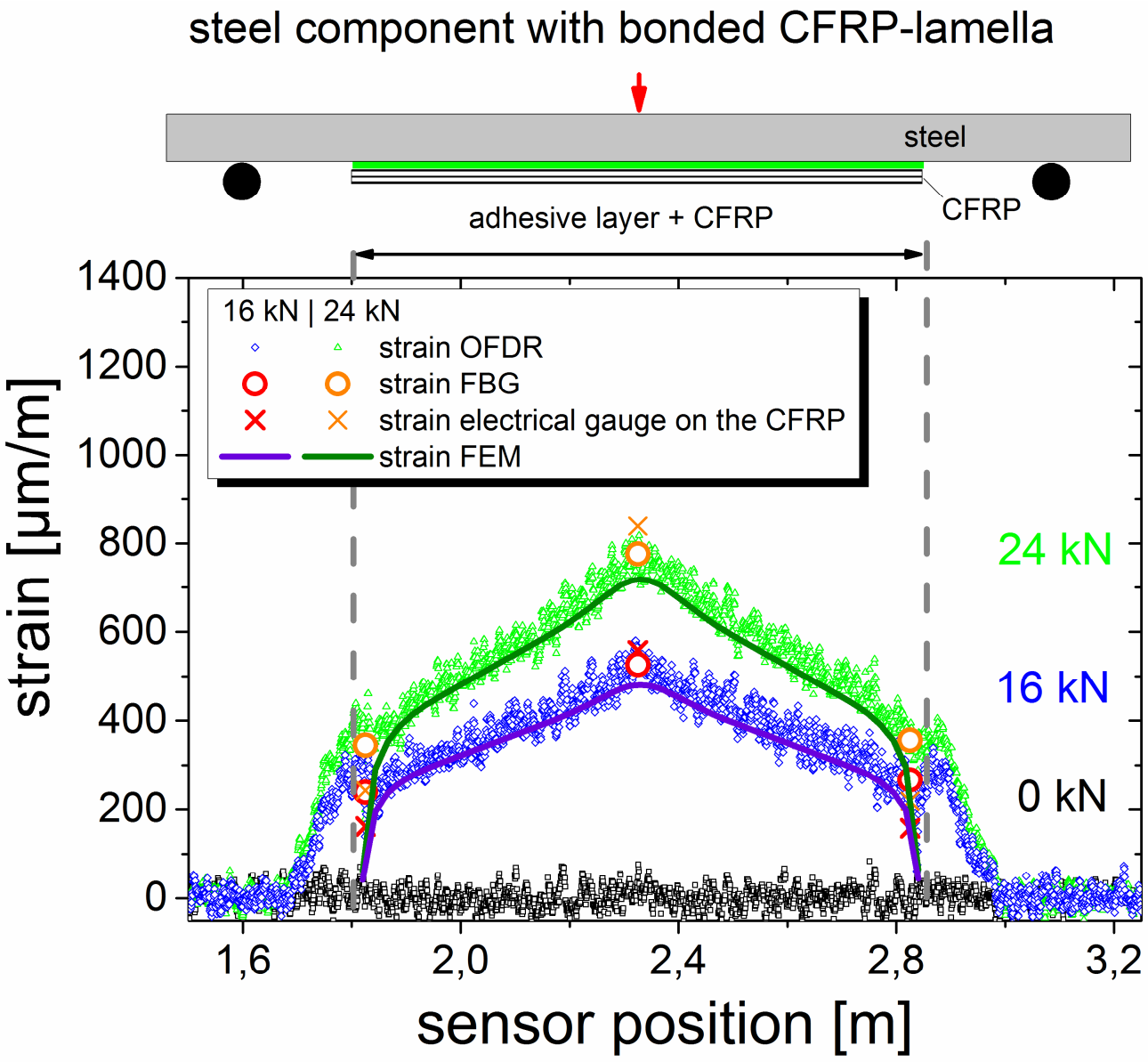


Figure 3: Comparison of fiber-optical sensor data with calculated strain using FEM of a steel components with bonded CFRP-lamella

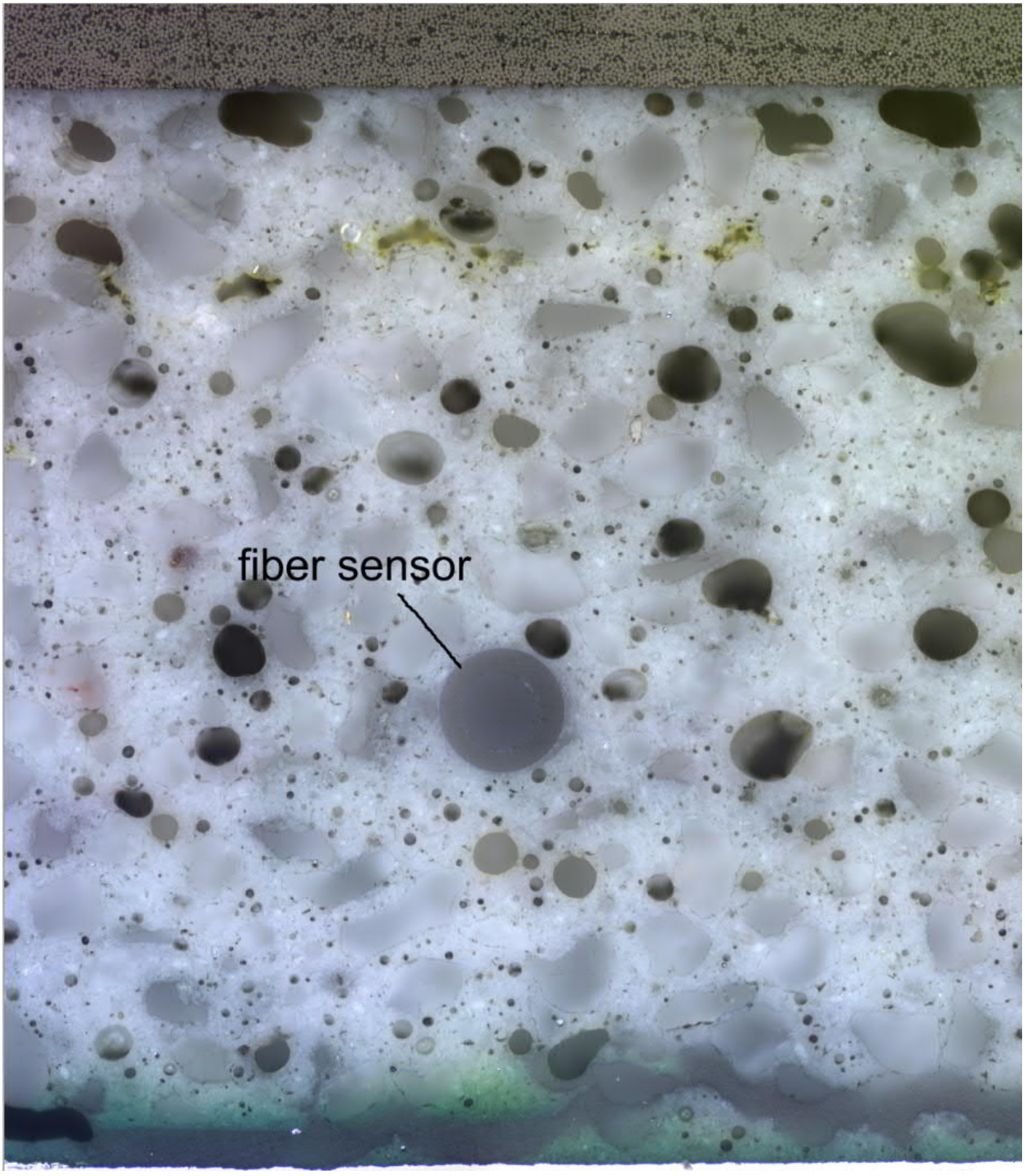


Figure 4: Light microscopy image of a section of a steel-CFRP-joint with integrated fiber-optical sensor

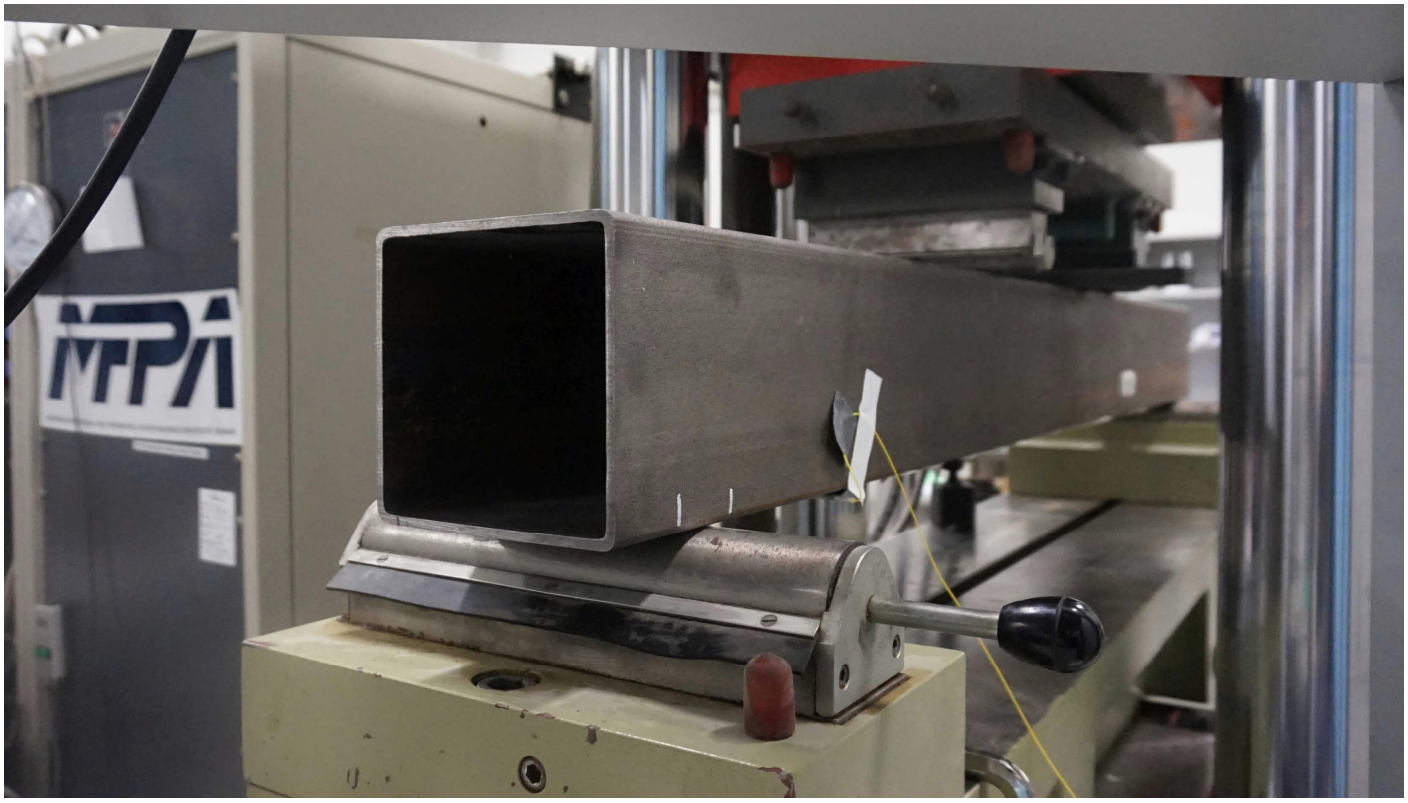


Figure 5: Image of components test on square profile with bonded CFRP-lamella and in the adhesive integrated fiber-optical sensors