UPC – BarcelonaTech experience on the use of Rayleigh based distributed optical fiber sensors for SHM of concrete structures

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Outline

- Introduction
- Distributed Optical Fiber Sensors (DOFS)
- Laboratory Experiment with embedded DOFS
- Conclusions
Introduction – Fiber Optic Sensors

Cylindrical symmetric structure that is composed by a central “core” with a **diameter** between 4 and 600 µm and a uniform refractive index

Advantages:
- Immunity from electromagnetic interferences
- Chemically inert – free from corrosion
- Withstand high temperatures
- Small and lightweight
Introduction – Fiber Optic Sensors

All possible crack openings are covered by the extension of the sensor
Scattering in Optical Fibers

DOFS

Light Source

Continuous sensing element

Light

Light backscatter provides three different components

antiStokes Components

Stokes Components

Rayleigh

Raman

Brillouin

Brillouin

Raman

\( \Delta \nu_b \sim 35 \text{ MHz} \)

\( 88 \text{ pm} \)

\( G_b \)

\( \lambda_0 - \Delta \lambda_0 \)

\( \lambda_0 = 1550 \)

\( \lambda_0 + \Delta \lambda_0 \)

\( \Delta \nu_0 \sim 11 \text{ GHz} \)

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Optical Backscatter Reflectometer - OBR

1. OBR system measures the **Rayleigh backscatter** as a function of length in an optical fiber with high spatial resolution (**1mm**)

2. External stimulus

3. Temporal and spectral shifts in the local backscattered pattern

4. Shifts can be measured and scaled to give distributed **strain** or **temperature** measurements

- Short range (50-70 m)
- High spatial resolution (1 mm)

Swept wavelength interferometry (fiber is divided in small windows)
Laboratory test with embedded DOFS

Two small reinforced concrete beams load test:

100x180x800 [mm]

Main objectives:

- Feasibility of installation of DOFS directly on rebar element of reinforced concrete beam
- Comparison of strain measured at rebar and surface of the concrete
- Detect and locate damage (cracks) induced by bending moment
Laboratory test with embedded DOFS

Rebar tensile test

DOFS attached to the rebar
Laboratory test with embedded DOFS

Strain obtained by the DOFS over the segment attached to the rebar for the entire duration of the experiment

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Laboratory test with embedded DOFS

Comparison of strains obtained by the different instrumented sensors

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Laboratory test with embedded DOFS

Beam 1

Beam 2
Laboratory test with embedded DOFS

**Beam 1** - Cyanoacrylate

**Beam 2** – Two-component epoxy
Laboratory test with embedded DOFS

**Front - Interior View**

- FI

**Adhered Fiber**
- Non-Adhered Fiber

**Front - Exterior View**

- FE-H1
- FE-H2
- FE-H3

**Bottom - Exterior View**

- BE-H1
- BE-H2

**Symbols:**
- FI – Front Interior
- FE-H(n) – Front Exterior Horizontal
- BE-H(n) – Bottom Exterior Horizontal

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Laboratory test with embedded DOFS

Applied Load - Beam 1

Applied Load - Beam 2
Laboratory test with embedded DOFS

Strain obtained by the DOFS over the entire length of the fiber for the entire duration of the experiment

Beam 1

Cracking
Laboratory test with embedded DOFS

Strain obtained by the DOFS over the entire length of the fiber for the entire duration of the experiment

Beam 2

Cracking

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Laboratory test with embedded DOFS

Applied Load - Beam 1

Applied Load - Beam 2

F(crack)
Fiber stopped working

F(crack)
Fiber stopped working
Laboratory test with embedded DOFS

BEAM 1

Strain obtained by the DOFS over the segment BE-H2 before cracking

BEAM 2

Strain obtained by the DOFS over the segment BE-H2 before cracking

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Evolution on DOFS measured strain on segment FI - Beam 1

Evolution on DOFS measured strain on segment FI - Beam 2

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- **Fl vs Strain Gauges [10.81 kN] - Beam 1**
- **Fl vs Strain Gauges [11.23 kN] - Beam 2**

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Conclusions

- Proven feasibility of implementing an optical fiber with minimal coating directly to a embedded rebar element;

- Proven feasibility on the detection and location of damage with this implementation technique;

- Possibility of simultaneously measuring a large number of structural points with the use of a single sensor;

- Fairly good agreement of the optical fiber data when compared with the strain gauges;

- Poor performance of the optical fiber after the occurrence of damage in the location of the crack, specially in its embedded segment;

Future work:

- Analysis of different adhesives and bonding mechanisms between the fiber and the structure.

- Study of the long-term reliability of this technology on concrete structures.
THANK YOU!

Questions?

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