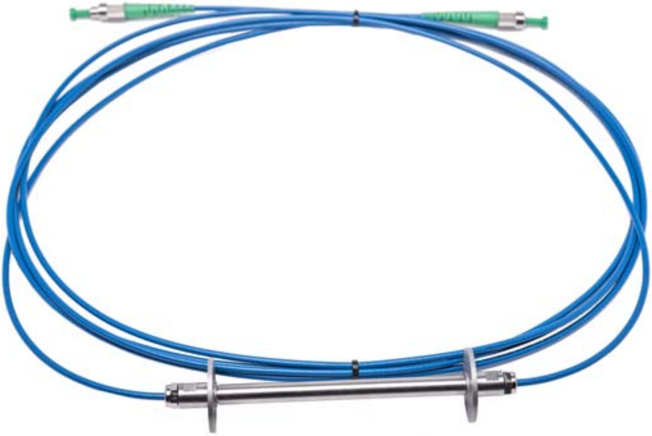
Installation Guide

English



FS62

Embedded Strain Sensor

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Sensor Design Version: v1.0

1 Technical Details

1.1 General Information

This installation guide applies to the following products:

Part Number	Description
K-FS62-50-11-302	FS62 – Embedded Strain Sensor • Outdoor • FC/APC
K-FS62-50-13-302	FS62 – Embedded Strain Sensor • Outdoor • SC/APC
K-FS62-50-10-302	FS62 – Embedded Strain Sensor • Outdoor • NC

1.1.1 Overview

The FS62 - Embedded Strain Sensors are Fiber Bragg Grating (FBG) based sensors, designed to be directly cast into concrete wet mix.

1.1.2 Characteristics

: Robustness

Long-term reliability ensured by innovative sensor design, careful selection of materials and IP68 packaging.

: Completely passive

Inherent immunity to all electromagnetic effects (EMI, RFI, sparks, etc.) and safe operation in hazardous environments.

: High multiplexing capability

Connection of a large number of sensors to a single optical fiber, reducing network and installation complexity.

: Remote sensing

Large distance between sensors and interrogator (several kilometers).

: Compatible with most interrogators

Provided with calibration sheet, allowing easy and accurate configuration.

: Self-referenced

Based on the measurement of an absolute parameter - the Bragg wavelength - independent of power fluctuations.

1.1.3 Applications

HBM FiberSensing strain sensors can be used in several strain measuring applications. They are particularly suited for structural health monitoring in large structures (SHM).

: Civil Engineering
: Transportation
: Energy
: Aeronautics
: R&D

1.1.4 Quality

All HBM FiberSensing's processes are strictly controlled from development to production. Each product is subjected to high standard performance and endurance tests, individually calibrated and checked before shipping.

HBM FiberSensing, S.A. concentrates all optical sensing activity of HBM and is an ISO 9001:2008 certified company.

1.1.5 Accessories

The implementation of complex sensing networks in large structures is made simpler with HBM FiberSensing accessories. These include cables especially designed to resist harsh environments as in civil engineering, not only during construction, but also during the lifetime of the structure (humidity, corrosion, etc.).

1.2 General Specifications

Sensor	
Sensitivity[1)]	1.5 pm/µε
Measurement range	±2500 µε
Gauge length	104 mm
Resolution[2)]	1 µε
Optical	
Central wavelength	1500 to 1600 nm
Spectral width (FWHM)	< 0.2 nm
Reflectivity	> 65%
Side lobe suppression	> 10 dB
Inputs / Outputs	
Cable type	Ø 3 mm outdoor (armor)
Cable length	2 m each side (±5 cm)
Connectors	FC/APC SC/APC NC (No Connectors)
Environmental	
Operation temperature	-20 to 80 ºC
Protection class	IP68
Mechanical	
Materials	Stainless steel
Dimensions	140 x Ø 30 mm
Weight	60 g

1) Typical values
2) For 1 pm resolution in wavelength measurement

2 Sensor Installation

2.1 List of Materials

Included Material

Embedded Strain Sensor

List of Needed Material

Clumps	Plastic wire clumps
Tube	Flexible and resistant protection tube
Box	Protection box to be embedded (optional)
Labels	Colored tape/heat shrinking tube/…
Protection	Silicone or foam

2.2 Preparing the Structure

The embedded strain sensor is a sensor prepared to be embedded in concrete. Its design includes ruggedized cables that resist such an environment. Nevertheless, whenever possible, further protection of cables should be performed on the cables path.

Prepare the sensor cables path with an appropriate, flexible and resistant tube.

Fig. 2.1

Fig. 2.2

Depending on the control on the construction site, HBM FiberSensing suggests two different solutions regarding the access to the sensor connections:

If the stripping of the concrete can be closely controlled, the protection tube can pass directly through a hole in the formwork (*Fig. 2.3 and Fig. 2.4*). Later, when the form-work is removed, a box can be placed over the exit of the cables so that connections can be conveniently protected.

Fig. 2.3

Fig. 2.4

Fig. 2.5

Fig. 2.6

If the stripping cannot be controlled, it is advisable to use embedded protection boxes. Fix the box to the formwork with screws that can be later on removed before the stripping.

Important

Make sure the construction workers are instructed that it is necessary to disconnect the boxes from the formwork before removing it.

2.3 Placing the Sensor

Carefully take the sensor out of the box.

Place it on the structure with the desired orientation. Fix the buffer as close to the sensor as possible making sure that the interface of the sensor and the buffer is not being forced.

Fig. 2.7

Fig. 2.8

If there is more than one sensor protected by the same tube it is advisable to mark the end of the buffer so that the sensors can be identified later on. Use, for example, colored tape or heat shrinkable tube. Be extremely careful with the heat application on the shrinkable tube for the buffer is sensible to high temperatures.

Control the path of the buffers with plastic wire clamps ensuring that the exposed buffers (before entering the protection tube) do not have tight curves and that it is protected by the reinforcement during the concreting operations and vibration (*Fig. 2.9*).

Fig. 2.9

Fig. 2.10

Close the end of the protection tube with polyurethane foam, silicone or similar (*Fig. 2.10*).

2.4 Concreting

Fig. 2.11

Fig. 2.12

The concreting process is a tough operation on the sensors, specially the vibration of the concrete.

One way of protecting the sensors from the vibrating equipment, as well as from the heavier aggregates, is to place a net on top of the sensors location.

Important

Despite all the protections you may have planned, make sure the operations are closely supervised and inform the workers about the installed sensors.

3 Sensor Configuration

3.1 Sensor Calibration Sheet

Every HBM FiberSensings sensor is provided with a calibration sheet. The layout of this document is the same for all strain sensors.

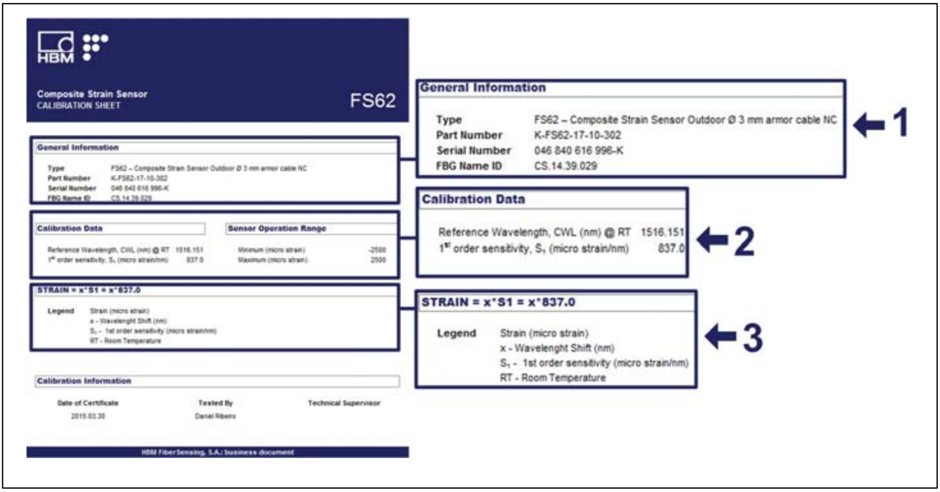

Fig. 3.1

3.1.1 General information

Number **1** in *Fig. 3.1* shows the general information on the particular sensor, such as its type, the sensor part number, its serial number and the production tracking number, the FBG ID.

3.1.2 Calibration Data

Under the calibration data table (number **2** in *Fig. 3.1*), there is the most important information on the strain sensor: its central wavelength at room temperature and its sensitivity – values that should be used for strain computation.

3.1.3 Strain Computation

Number **3** in *Fig. 3.1* exemplifies the calculations that should be performed for wavelength measurement to strain conversion. The strain variation, under constant temperature, of a embedded strain sensor is given by the product of wavelength shift from the zero moment by the sensor's sensitivity.

$$strain = x * S \leftrightarrow strain = (WL - CWL) * S$$

Fig. 3.2

Where

- x is the wavelength shift in nm
- S is the given sensitivity in με/nm
- CWL is the central wavelength of the sensor at the zero moment in nm
- WL is the measured wavelength in nm.

3.2 Temperature Effect on the Sensor

The embedded strain sensor, as most sensors, is sensitive to temperature changes. The temperature induced wavelength shift can be confused as strain. For its correction, a representative temperature sensor should be used.

3.2.1 Effect of the Temperature on the Sensor

The temperature dependence of the embedded strain sensor is:

$$7,32 \times \Delta T$$

Fig. 3.3

Where:

ΔT is the temperature shift from the zero moment, in ºC, measured with a representative temperature sensor.

This means that to compensate for the effect of temperature on the sensor measurement the computation should be:

$$strain = x * S - 7.32 \times \Delta T \leftrightarrow$$
$$strain = (WL - CWL) * S - 7.32 \times \Delta T$$

Fig. 3.4

Information

This computation only corrects the effect of temperature on FBG and does not take into account the thermal expansion of the base material where the sensor is attached to.

3.2.2 Effect of the Temperature on the Sensor and on the Base Material

To compensate also for the deformation of the structure due to temperature effects, the computation should be done considering the coefficient of thermal expansion (CTE) of the structure.

The total strain variation of a structure is:

$$strain = strain_{Load} + strain_{Temp\ on\ FBG} + strain_{Temp\ on\ Structure} \leftrightarrow$$
$$strain = strain_{Load} + strain_{Temp\ on\ FBG} + CTE_{Structure}\Delta T \leftrightarrow$$

Fig. 3.5

Where

- Strain is total strain in $\mu\varepsilon$
- $Strain_{Load}$ is the strain due to loading that we want to measure in $\mu\varepsilon$
- $Strain_{Temp\ on\ FBG}$ is the temperature induced strain measurement, as explained above, in $\mu\varepsilon$
- $Strain_{Temp\ on\ Structure}$ is the temperature induced strain on the structure, in $\mu\varepsilon$
- $CTE_{Structure}$ is the thermal expansion coefficient of the structure material in $°C^{-1}$

Meaning that to compensate the deformation of the structure due to temperature effect, it is necessary to know the CTE value of the material of the structure where the sensor is fixed on.

The strain caused by loading can then be computed as:

$$strain_{Load} = strain - strain_{Temp\ on\ FBG} - CTG_{Structure}\Delta T \leftrightarrow$$
$$strain_{Load} = x * S - 7.32 \times \Delta T - CTE_{Structure} \times \Delta T$$

Fig. 3.6

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