Mounting Instructions

English

FS62RSS, FS63RTS

Rugged Strain and Temperature Sensors

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1 General Information

The following instructions refer to the installation procedure of FS62RSS Rugged Strain Sensors and FS63RTS Rugged Temperature Sensors.
These sensors can be delivered individually or in arrays of sensors pre-assembled at HBM FiberSensing facilities.

Material Numbers	
Strain Sensors	**Temperature Sensors**
K-FS62RSS	K-FS63RTS
	1-FS63RTS-ARM/1515
	1-FS63RTS-ARM/1525
	1-FS63RTS-ARM/1535
	1-FS63RTS-ARM/1545
	1-FS63RTS-ARM/1555
	1-FS63RTS-ARM/1565
	1-FS63RTS-ARM/1575
	1-FS63RTS-ARM/1585
	1-FS63RTS-ARM/1595
Sensor Arrays	
K-FS76ARM	

1.1 newLight technology

The FS62RSS and FS63RTS are based on the **newLight®** technology developed by HBM FiberSensing to combine particular advantages of the FBG overcoming technical compromises that existed so far. newLight® sensors employ **high strength fiber coatings** and **different FBG fabrication techniques** to ensure increased strain measurement ranges, enhanced fatigue resistance and higher measurement accuracy. **The low bend loss, telecom compatible fiber** opens the possibilities for innovative sensor designs as well as the straightforward usage of multiplexed sensors on the same fiber even if kilometers apart. The technology is completely **passive, self-referenced** and **compatible with most interrogators**.

2 Embedded Option Sensor Installation

2.1 List of materials

Included material
FS62RSS Rugged Strain Sensor(s)
FS63RTS Rugged Temperature Sensor(s)

Needed material
Fixation: Plastic wire clumps
Protection: Silicone or foam Flexible and resistant protection tube Protection box to be embedded (optional)
Identification: Colored tape/heat shrinking tube/…

2.2 Preparation of the installation area

The rugged strain and temperature sensors are prepared to be embedded in concrete. The ruggedized sensor's design includes protected cables for 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 from the connector location to the sensor location.

Fig. 2.1 Protection tube from the cable collection point to the sensor installation area

Fig. 2.2 Cable routing detail

HBM FiberSensing recommends two different approaches regarding the access to the sensors connections:

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

Fig. 2.3 Direct exiting from the formwork (inside view)

Fig. 2.4 Direct exiting from the formwork (outside view)

Fig. 2.5 Protection box for optical connections protection example

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

Fig. 2.6 Example of an embedded protection box

Information

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

2.3 Fixing the sensor

Carefully take the sensor out of the box.

Place it on the structure with the desired orientation. Fix the sensor either by hanging between rebars (*Fig. 2.8*), or attached to a rebar (*Fig. 2.7*). Make sure that that the interface of the sensor and the cables are not being forced.

Fig. 2.7 Sensor's positioning

Fig. 2.8 Sensor's positioning

2.4 Sensor identification

If there is more than one sensor protected by the same tube it is advisable to mark the end of the cables so that the sensors can be identified later on. Use, for example, colored tape or heat shrinking tube.

Fig. 2.9 Sensor's identification

Information

Be extremely careful with the heat application on the shrinking 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. 2.10 and Fig. 2.11*).

Fig. 2.10 Cable routing

Fig. 2.11 Cable routing

Close the end of the protection tube with polyurethane foam, silicone or similar (*Fig. 2.12*).

Fig. 2.12 Protection tube sealing

2.5 Concreting

The concreting process is a tough operation on the sensors, especially if mechanical vibration is applied to the concrete.

Fig. 2.13 Sensor during concreting

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.

Fig. 2.14 Sensor area protection

Information

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

3 Surface Mount Option Sensor installation

3.1 List of materials

Included material
FS62RSS Rugged Strain Sensor(s)
FS63RTS Rugged Temperature Sensor(s)

Needed Equipment
Drilling machine

Needed material
Fixation: M6 Anchors, Flat Washers, Bolts and Thread Locking Adhesive Suggested: Hilti HSA-R M6 5/-/- cpl; Loxeal 55-03 Thread Locker
Protection: Protection box or cover to be embedded (optional)
Hammer
Drill bit diameter 6mm
Spanner Wrench 10mm

3.2 Preparation of the surface

The surface where the sensor is to be installed should be regular.

Make sure of that there are no major irregularities that could interfere with the sensor's fixation to the structure.

Fig. 3.1 Regularizing the surface

- ► Using a hammer and a chisel or similar, remove major irregularities that could interfere with the correct positioning of the sensor.
- ► Mark the position of holes to drill considering the measurement direction and the sensor characteristics.

3.3 Preparing anchoring points

For fixing the sensor needs four anchoring points, two to each side of the sensor, 120 mm apart.

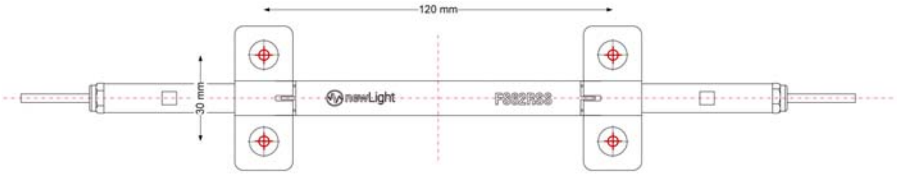

Fig. 3.2 Fixing points marking

- ► Mark the four points aligned with the desired measuring direction and centered with the measurement point.

Tip

A paper gauge is provided to support on the drilling position. Align it with the desired direction and centered at the marked point measuring point and attach it to the surface. Drill through the paper.

Information

The following procedure refers to the installation on a (cracked/non-cracked) concrete surface. For others base materials, procedure adaptations or specially designed accessories might be necessary.

- Drill the holes according to the chosen anchors. (suggested hole depth: 55 mm)
- Clean the holes and remove the inside dust.

Fig. 3.3 *Drilled and clean hole*

- Install the anchors in the holes, leaving 10 mm outside.

Information

An hammer might be needed for this operation.

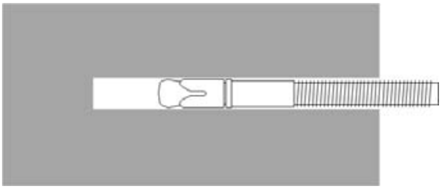

Fig. 3.4 *Inserted anchor*

- Verify the screws position with a measuring tape.
- Introduce the washes and the nuts.

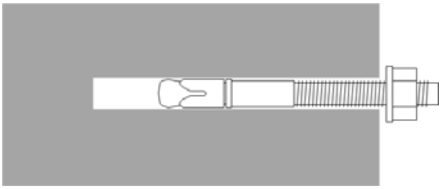

Fig. 3.5 *Fastening the nut*

► Insert the washes and fasten the nuts tightly.
(Recommended tightening torque: 5 Nm)

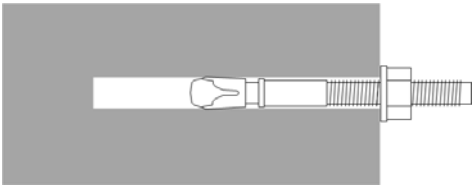

Fig. 3.6 *Tightening the nut to open and secure the anchor*

► Remove the nuts and the washes.

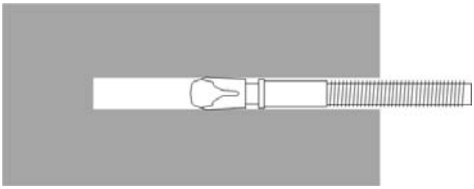

Fig. 3.7 *Secured anchor*

3.4 Installing the sensor

- ► Carefully take the sensor out of the transportation box and place it on the supports.

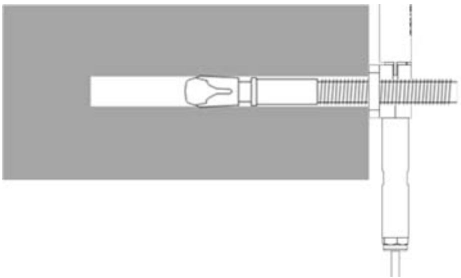

Fig. 3.8 Placing the sensor on the anchors

- ► Slightly fasten the nuts following the opposing diagonal direction (first nut 1, then 4, then 3 and 2).

Fig. 3.9 Nut position

- ► Adjust the sensor to its correct direction.
- ► Tightly fasten the nuts following the same procedure. Recommended minimum torque of 5 Nm.

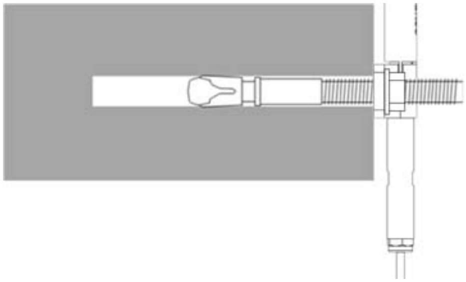

Fig. 3.10 Fastened sensor

3.5 Routing and protecting the cables

Sensor cable should be routed ensuring that cables are not hanging and curvatures are kept within the limits for the used cable The cable should be fixed by means of clamps or strong tape, for example (*Fig. 3.11*). In case there are splice protections, ensure that the splices are also well fixed.

Fig. 3.11 Cable routing

Plastic corrugated tubes can also help routing the longer lead cables that will connect to the interrogator (*Fig. 3.12*).

Fig. 3.12 Cable protected with corrugated tubes

Excess cable should be coiled and stored in a suitable IP case, so it can be used in case of network refurbishment (*Fig. 3.13*).

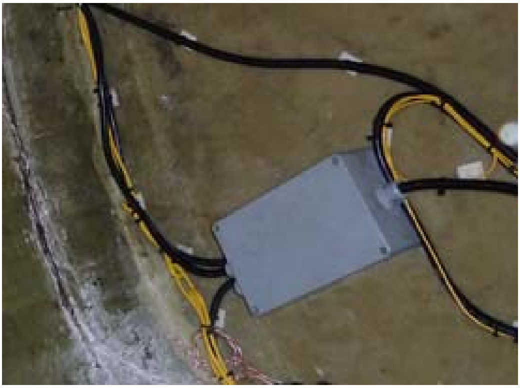

Fig. 3.13 Protection boxes for extra cable and connections

3.6 Protecting the sensor

The surface mount version of the strain sensor is prepared to withstand outdoor conditions. However, it might be necessary to provide further mechanical protection. For example, by using a plastic or metallic cover. Protection accessories are not provided.

4 Sensor Configuration

4.1 Sensors documentation

Calibrated HBM FiberSensing Sensors are delivered with a Calibration Sheet. Remaining sensors are delivered with a sensor Characteristic Sheet that contains important information for sensor configuration.

In the case sensors are delivered in arrays of pre-assembled sensors, a resume table with the relevant calibration information is provided in alternative.

Within the sensor's packing this installation instructions document is delivered in a printed version. Installation instructions can also be downloaded from HBM website (www.hbm.com).

4.2 Measurement computation

4.2.1 Temperature

The calculations that should be performed for converting a wavelength measurement into temperature are the shown in *Fig. 4.1*. The temperature value of a temperature sensor is given by a second order polynomial equation with coefficients obtained from the sensor calibration.

$$T = S_2(\lambda - \lambda_0)^2 + S_1(\lambda - \lambda_0) + S_0$$

Fig. 4.1 Temperature computation formula

Where

- T is the measured Temperature in ºC
- λ is the measured Bragg wavelength of the temperature sensor in nm

- λ_0 is the Bragg wavelength of the temperature sensor at reference temperature in nm
- S_0 is the zero order calibration factor (reference temperature) in ºC
- S_1 is the first order calibration factor in ºC/nm
- S_2 is the second order calibration factor in ºC/nm^2

When operating with catman® the values λ_0, S_0, S_1 and S_2 should be filled on the menu for temperature sensors configuration.

4.2.2 Strain

Strain sensors are not calibrated sensors. The characteristic sheet delivered with the sensor presents the sensor data for correct strain computation.

For the fiber Bragg grating strain sensors, wavelength variation including the effect of temperature is given by the equation as shown in *Fig. 4.2.*

$$\frac{(\lambda - \lambda_0)}{\lambda_0} = k \cdot \left(\varepsilon_{Load} + (TCS + CTE) \cdot (T - T_0)\right) \cdot 10^6$$

Fig. 4.2 Wavelength variation of a strain FBG due to strain and temperature effects

Where

- λ is the measured Bragg wavelength of the strain sensor in nm
- λ_0 is the Bragg wavelength of the strain sensor at the reference instant in nm
- k is the strain k factor of the strain sensor, dimensionless
- E_{Load} is the mechanical strain applied to the structure in µm/m
- *TCS* is the temperature cross sensitivity of the strain sensor in (µm/m)/ºC
- *CTE* is the thermal expansion of the material of the specimen the strain sensor is attached to in (µm/m)/ºC

- $T\text{-}T_0$ is the temperature variation since the reference instant to the measurement instant in ºC

Measurement with no compensation

If no temperature compensation is required the strain computation can be done as shown in *Fig. 4.3*.

$$\varepsilon = \frac{(\lambda - \lambda_0)}{k \cdot \lambda_0} \cdot 10^6$$

Fig. 4.3 Strain without temperature compensation computation formula

Where

- ε is the measured strain in μm/m
- λ is the measured Bragg wavelength of the strain sensor in nm
- λ_0 is the Bragg wavelength of the strain sensor at the reference instant in nm
- k is the strain k factor of the strain sensor, dimensionless

Measurement with temperature compensation using a temperature sensor

Calculating compensated strain, in μm/m, using a temperature sensor is straightforward as the output of a temperature sensor is a temperature value in ºC. The calculation is the depicted in *Fig. 4.4*.

$$\varepsilon_{Load} = \frac{(\lambda - \lambda_0)}{k \cdot \lambda_0} \cdot 10^6 - (TCS + CTE)(T - T_0)$$

Fig. 4.4 Strain computation with temperature compensation using a temperature sensor

Where

- ε_{Load} is the mechanical strain applied to the structure in µm/m
- λ is the measured Bragg wavelength of the strain sensor in nm
- λ_0 is the Bragg wavelength of the strain sensor at the reference instant in nm
- k is the strain k factor of the strain sensor, dimensionless
- *TCS* is the temperature cross sensitivity of the strain sensor in (µm/m)/ºC
- *CTE* is the thermal expansion of the material of the specimen the strain sensor is attached to in (µm/m)/ºC
- T is the measured temperature of the used temperature sensor in ºC
- T_0 is the temperature from the temperature sensor at the reference instant in ºC

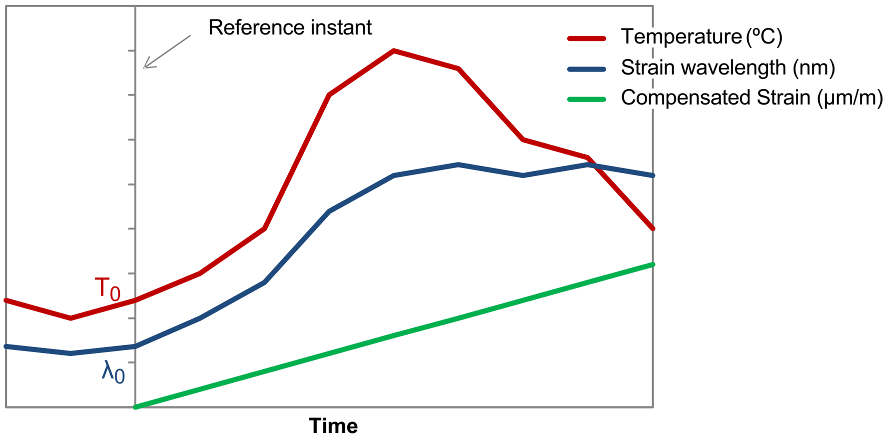

Fig. 4.5 Reference instant for temperature compensated strain measurement when using a temperature sensor for compensation

Measurement with temperature compensation using a compensation element

Strain measurement can also be correctly compensated using a compensation element based on FBG technology. Different approaches can be used:

- a temperature sensor without calibration certificate
- a strain sensor installed on a strain-free area of the same material
- a strain sensor installed on a strain-free material with a known CTE

The computation of strain can then be performed using the equation from *Fig. 4.6*.

$$\varepsilon_{Load} = \frac{\lambda - \lambda_0}{k \cdot \lambda_0} \cdot 10^6 - \frac{\lambda_{Tc} - \lambda_{0_{Tc}}}{\lambda_{0_{Tc}}} \frac{(TCS + CTE)}{TCF} \cdot 10^6$$

Fig. 4.6 Strain computation with temperature compensation using an FBG compensation element

Where

- ε_{Load} is the mechanical strain applied to the structure in µm/m
- λ is the measured Bragg wavelength of the strain sensor in nm
- λ_0 is the Bragg wavelength of the strain sensor at the reference instant in nm
- *k* is the strain k factor of the strain sensor, dimensionless
- λ_{TC} is the measured Bragg wavelength of the compensation element in nm
- λ_{0TC} is the Bragg wavelength of the compensation element at the reference instant in nm
- *TCS* is the temperature cross sensitivity of the strain sensor in (µm/m)/ºC
- *CTE* is the thermal expansion of the material of the specimen the strain sensor is attached to in (µm/m)/ºC
- *TCF* is the temperature compensation factor of the compensation element in (µm/m)/ºC. For an uncalibrated temperature sensor the value is given on

the sensor’s characteristics sheet. For a strain sensor attached to a specific material TCF can be calculated as shown in *Fig. 4.7*.

$$TCF = (5.7 + k \cdot CTE_{TC})$$

Fig. 4.7 Temperature compensation factor computation

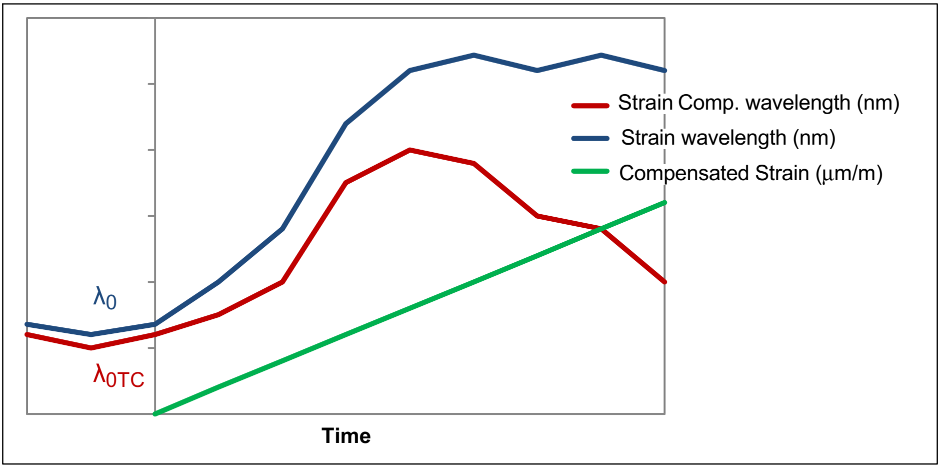

Fig. 4.8 Reference instant for temperature compensated strain measurement when using an FBG compensation element

Measurement with bending moment correction

When measuring on an element using a sensor that is far away from the attachment surface there may be an “error” on the measurement because the distance between the measuring point/alignment and the neutral axis is different to the distance between the installation surface and the neutral axis.

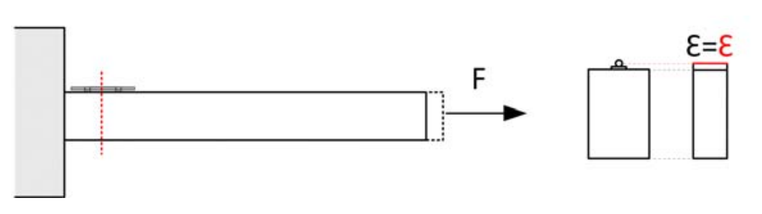

Fig. 4.9 Strain on pure axial deformation

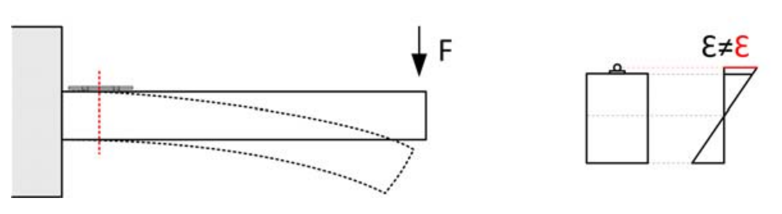

Fig. 4.10 Strain on pure bending moment

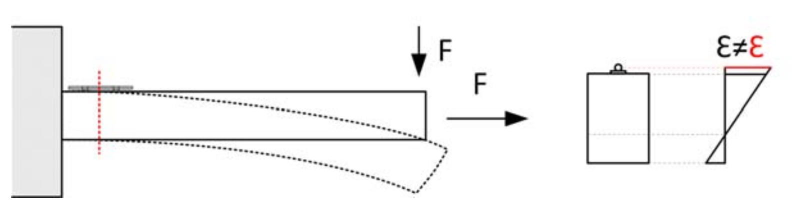

Fig. 4.11 Strain on axial load and bending moment

This becomes of high importance when the distance between the sensing element on the sensor to the attachment surface is relevant. This distance on the FS62RSS Rugged Strain Sensor to be Surface Mounted is 10 mm (h_2 on *Fig. 4.11*).

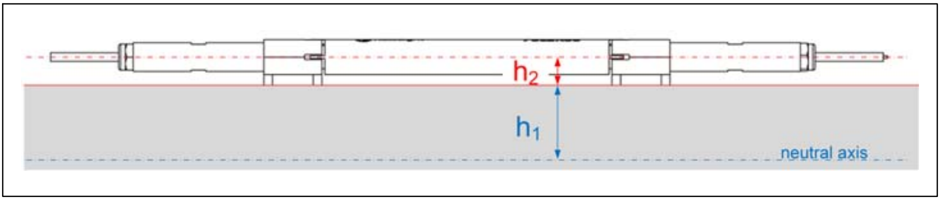

Fig. 4.12 Distance of the FBG to the mounting surface on the FS62RSS Surface Mount option

However, knowing the distance to the neutral axis (h_1) the measured strain from the sensor can be corrected into strain on the surface by a geometrical factor:

$$\varepsilon_{surface} = \frac{\lambda - \lambda_0}{k \cdot \lambda} \cdot \frac{h_1}{h_2 + h_1} \cdot 10^6$$

Fig. 4.13 Strain computation bending effect correction

Where

- $\varepsilon_{surface}$ is the mechanical strain on the measuring surface in µm/m
- λ is the measured Bragg wavelength of the strain sensor in nm
- λ_0 is the Bragg wavelength of the strain sensor at the reference instant in nm
- k is the strain k factor of the strain sensor, dimensionless
- h_1 is the distance from the measuring surface to the neutral axis in mm
- h_2 is the distance from the measuring surface to the FBG in mm (10 mm for the FS62RSS Surface Mount Option)

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