Bridge bearing/expansion joint monitoring

Assess functionality and responsiveness of the bearings rotation/expansion joint with Resensys Wireless Displacement and WirelessTilt/ Inclination SenSpot Sensors data analysis

A **bridge bearing** is a component of a bridge which typically provides a resting surface between bridge piers and the bridge deck. The purpose of a bearing is to allow controlled movement of the structure and thereby reduce the stresses involved. Possible causes of movement are thermal expansion and contraction, creep, shrinkage of/ within the structure, or fatigue due to the properties of the material used for the bearing. For instance, abnormal movements in the bearing/ expansion joint may cause abnormal movement in the piers of a bridge.

An **expansion joint** or movement joint is an assembly designed to hold parts together while safely absorbing temperature-induced expansion and contraction of building materials, and vibration, or to allow movement due to ground settlement or seismic activity. They are commonly found between sections of buildings, bridges, sidewalks, railway tracks, piping systems, ships, and other structures. Bridge expansion joints are designed to allow for continuous traffic between structures while accommodating movement, shrinkage, and temperature variations on reinforced and pre-stressed concrete, composite, and steel structures. They stop the bridge from bending out of place in extreme conditions, and also allow enough vertical movement to permit bearing replacement [1] without the need to dismantle the bridge expansion joint.

The Resensys Wireless Displacement and Tilt SenSpot sensors data analysis can be used for bridge bearing/expansion joint monitoring. Resensys wireless displacement and tilt sensors are designed to provide accurate small scale displacement/ tilt measurements over long periods of time, allowing them to provide base-level data and also continuously monitor for changes that could indicate changes in the effectiveness of these important bearings or joint functionality. Ensuring that these bearings/ joints are functioning as designed can pre-empt expensive repairs or structural failures or other structural damage. This can allow for improved asset management decisions. By utilizing ultra-low power, wireless technology, Resensys decreases installation and maintenance costs of monitoring these elements.

The applicable, measurable and monitorable quantities for bridge bearing and expansion joint measuring are displacement, tilt and ambient temperature. Resensys SenSpots are able to monitor these structural quantities in concrete, steel and composite materials under wet, humid and extreme weather conditions. The product is corrosion resistant and can withstand salty environments.

A Resensys Bridge Bearing/Expansion Joint Monitoring solution comprises wireless Displacement SenSpot sensor and/or wireless Tilt SenSpot sensor on the location of bearings/expansion, a SeniMax Gateway to transmit data away from the site and the SenScope display user-interface.

Tilt (bearing rotation) SenSpot sensor and displacement SenSpot sensor on bridge bearing to assess bearing functionality

Resensys SenSpot sensors are easily placed/ installed on critical bearings/expansion joints as determined by inspection, finite element modeling or authority's/client's suggestion. Since they are wireless, no additional wiring is required, and the sensors are mounted with adhesive or flange mounted depending on the application. A Senimax data acquisition unit is conveniently mounted nearby or conveniently mounted within 1.0Km (0.62miles) free space of the Senspot Sensors and a SenScope module is installed on the client's/authority's laptop or PC.

A complete Resensys SHM system includes software and hardware components for (1) the reliable collection of SenSpot data, (2) aggregation of the data, (3) the addition of timestamps, (4) communication of encrypted data to a remote server, and finally, (5) an interface for data visualization and detection of structural issues. Figure below shows a picture of a practical Resensys SHM system, which can be used for structural monitoring.

The system includes the following components:

- SenSpot sensors (displacement and tilt SenSpots): which are attached to a bridge (A few tens of sensors per structure, depending on design and monitoring needs).
- SeniMax: which collects SenSpot data at the site and sends it to a remote server (one unit can cover as many as 100 SenSpots).
- Repeater: may be used to extend the range of the SenSpot sensors.
- SenScope: software for data analysis and visualization

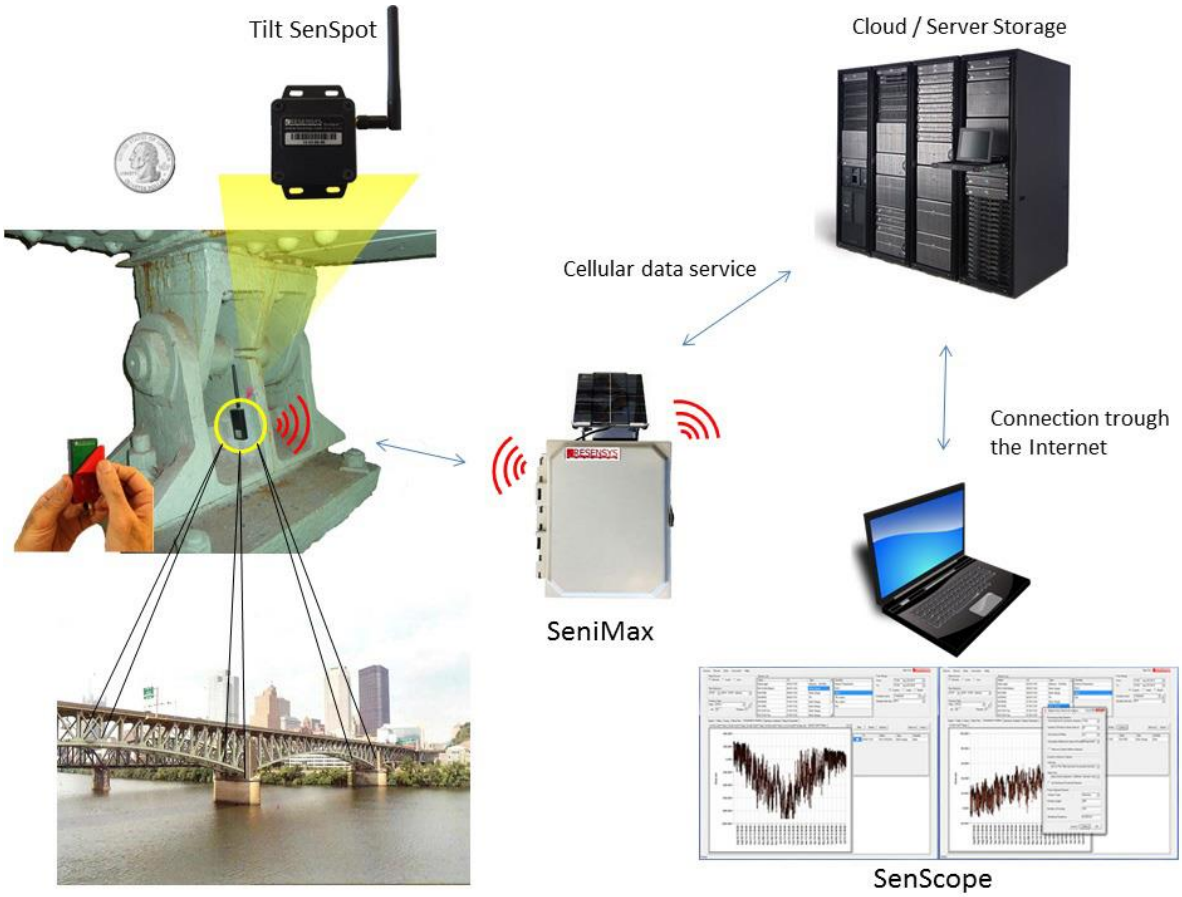
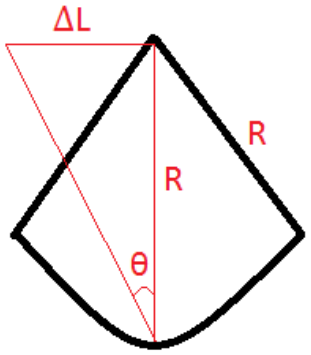


Illustration of Resensys SHM based on SenSpot sensors for bearing/expansion joint monitoring

Technical Note: Functionality of the bearings rotation and responsiveness of pier bearings are assessed by comparing **measured responses rate** (attained from regression analysis of Displacement/Tilt and corresponding temperature data during monitoring time period) with **expected value** (attained from effective length of spans and steel thermal expansion coefficient).

Expected response to temperature for a bearing would be obtained as follows:



$\theta = tg^{-1}(\Delta L/R)$

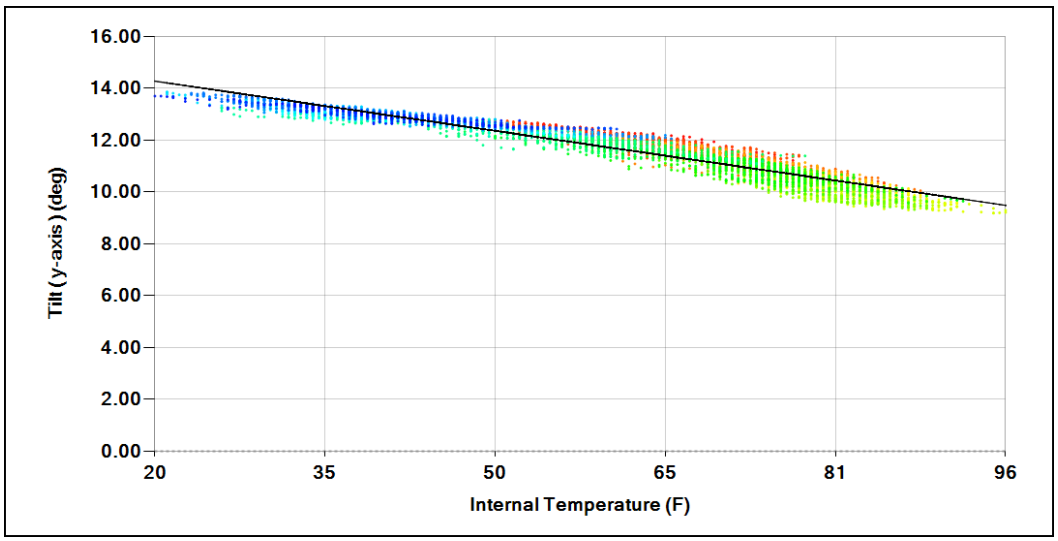
L: Total expandable length
c: Steel thermal expansion coefficient
ΔL: Expansion per degF at the bearing
R: Bearing radius
θ: Bearing rotation **(Expected response to temperature)**

$\Delta L = L \times c$

$\theta = tg^{-1}(\Delta L/R)$

Bridge bearing front view and definition of its geometric properties

Measured response to temperature for Tilt gauges would be obtained from regression analysis:



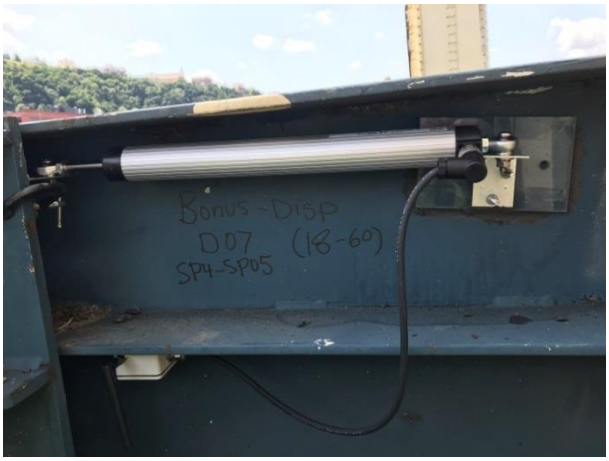
Linear Equation Trend Line: Tilt = 15.5104 - **0.0629***Internal Temperature

Linear regression between tilt (bearing rotation) and temperature for a bridge bearing in a specific time period

By this way, it is found whether there are excessive movements of bearings or not. Furthermore, it can be seen bearings are responsive or non-responsive (frozen bearings).

Resensys Wireless Tilt/ Inclination SenSpot sensors on bridge bearings to assess bearings functionality

Resensys Wireless Displacement SenSpot sensor on bridge bearing to assess bearing functionality



Resensys Wireless Displacement SenSpot sensor on bridge expansion joint

Technical Specifications:

	Wireless Tilt SenSpot sensor	Wireless Displacement SenSpot sensor
Size (Dimension)	-Transmitter Dimension: 79.6mm(3.13")x74.6mm(2.94″) x 52mm(2.05") -AssemblyDimension:120.8mm (4.76") x 96.6mm (3.8")x149.9mm (5.9")	Model 2": 176mm [6.9"], Model 3": 201mm[7.9"], Model 4": 227mm[8.9"], Model 6": 277mm[10.9"]
Weight	180 g (6.3 oz.)	245 g (8.6 oz.)
Mounting	Flange-mount or adhesive tape	self-adhesive or flange-mount
Accuracy (Resolution)	-Narrow Range HRT: ≤0.0003^0 (5.2μrad) -Regular tilt : 0.1^0	0.1mm (4mil)
Measurement Range	-Operating range: • Narrow Range High Resolution Tilt : ± 0.5^0 (with respect to vertical position) • Regular tilt: all directions -Linear range: • Narrow Range HRT: ±1^0 • Mid-Range HRT: ±10^0 -Repeatability: • Narrow Range HRT: ≤0.001^0 (17.5μrad) • Regular Tilt:1^0 -Time constant: ≤1sec(High resolution tilt)	25mm (1"), 50mm (2"), 75mm (3"), 100mm (4"), 150mm(6"), 300mm(12")
Operating temperature	-40°C to +65°C(-40°Fto +150°F)	-40°C to+65°C(-40°F to +150°F)
Lifetime	battery life of 10 years (Ultra-low-power)	battery life of 10 years (Ultra-low-power)
Installation Time	1-2 minutes	1-2 minutes
Complementary sensing	temperature, battery voltage, etc.	temperature, battery voltage
Communication range	1.0km(0.62mile)free space	1.0km(0.62mile)free space
Power source	Replaceable lithium ion battery	Replaceable lithium-ion battery
Wireless communication	no wiring is required for data collection- IEEE 802.15.4	no wiring needed for deploying the system-IEEE 802.15.4