

Remote Retaining Wall Monitoring Using Resensys Wireless Tilt SenSpot™ Sensor

Purpose: this application note explains how to assess the functionality and stability of retaining walls with Resensys Wireless High-Resolution Tilt/Inclination SenSpot™ Sensors

Retaining walls are moderately rigid walls used for supporting soil laterally, so it can be held at different levels on both sides. Retaining walls are structures designed to harness soil to a slope that it would not naturally keep to (typically a steep, near-vertical or vertical slope).

They are used to bound soils between two different elevations often in areas of terrain possessing undesirable slopes or in areas where the landscape needs to be shaped strictly and engineered for more specific goals such as hillside farming or roadway overpasses.

Retaining walls are significant geotechnical structures to stabilize slopes in the vicinity of civil structures like highways, buildings, railway lines, and tunnels. These walls are frequently interacting with other infrastructure, contributing to the safety of transportation networks, particularly in mountainous areas. Thus, failure of these walls causes of death of highway users. Failures of retaining walls can also causes the repair or retrofit works that can lead to delays and huge financial loss due to closures of highway lanes. Structural monitoring can help to assess the condition of retaining walls to ensure the proper performance of these structures, especially in the presence of adverse environmental conditions.

These structures are conventionally monitored via visual inspection. This solution is very expensive and it cannot provide accurate information about the health of retaining walls or the condition of retaining wall faces.

Structural health monitoring (SHM) is the engineering branch where the serviceability of construction is evaluated by non-destructive, indirect measurements of physical properties like inclination, temperature, moisture content, etc. The maintenance and management of a retaining wall can benefit from continuous measurements compared to yearly inspections.

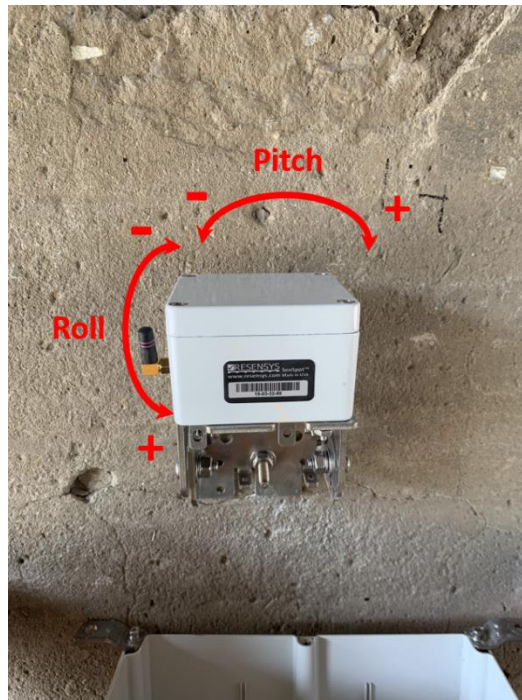
New technologies are available to make monitoring retaining walls more practical and affordable. By obtaining objective and measurable data, more effective and efficient retaining wall asset management systems can be implemented than those provided by traditional and subjective management systems, which are based on regular inspections alone.

The applicable, measurable, and monitorable quantities of retaining walls are tilt and ambient humidity/temperature.

The Resensys wireless SHM solution is well-suited for retaining wall monitoring. This system can provide peace of mind to retaining walls authorities, who have concerns about potential hazards that threaten

their structures, overload conditions, failures, and the corresponding risks of structural damage or possible human injury.

Wireless high-resolution tilt SenSpot™ sensors have been designed to assist authorities with this application. Wireless high-resolution Tilt SenSpot™ sensors are able to be installed on and within retaining walls, and they are capable of monitoring inclination of retaining walls in high precision (0.00016 degree or 0.5 arcseconds). This allows complete condition awareness and remote monitoring of retaining walls, and is particularly useful to allow quick assessment of conditions after events like severe floods.



Wireless Dual-Axis Incliner (Tiltmeter) SenSpot™ installed on a face of a retaining wall and its movement and sign conventions (Roll: tilting of the wall in longitudinal direction & Pitch: tilting of the wall in transverse direction)

By measuring inclination and temperature on a retaining wall face, the overall and detailed condition of a retaining wall face can be assessed, providing real time data of tilt quantities even when physical inspection is impossible due to icy or wet weather conditions or when the rate of inclination has the potential to exceed desired inspection levels.

Therefore, monitoring retaining walls by Resensys structural health monitoring system and wireless [SenSpot™](#) sensors, allows infrastructure owners/authorities to access accurate and real-time data easily for their future decisions. Moreover, this kind of monitoring is important to meet inspection and reporting requirements with respect to rehabilitation and reinforcement.

Additionally, changes in the temperature and/or positioning of the sun can produce non-negligible thermal effects which affect the slope of the retaining wall face and long-term structural behavior. All Resensys wireless sensors and devices including wireless tilt SenSpot™ provide ambient temperature readings, so additional temperature sensors are not needed. Consequently, thermally induced tilt, inclination, or deformation in retaining wall structure and face can be monitored easily.

A Resensys solution for monitoring of Retaining Wall comprises the following components:

- [SenSpot™](#) sensors (for tilt and ambient temperature): which are attached to a face of retaining walls. The required number of sensors per retaining wall structure depends on construction, field condition, or design requirements).
- [SeniMax™](#): gateway/data logger, which collects [SenSpot™](#) data at the site and sends it to a remote server (one unit can cover as many as 100 [SenSpot™](#) sensors).
- Repeater: may be used to extend the range of the [SenSpot™](#) sensors.
- [SenScope™](#): software for data analysis and visualization.

[Resensys Wireless Tilt SenSpot™](#) sensors are well-suited for retaining walls because of their continuous and accurate data collection, high rates of data transmission, and ability to withstand harsh/extreme weather conditions. They are wireless, and low-power, meaning that they are easy and cost effective to install and maintain, particularly in remote areas.

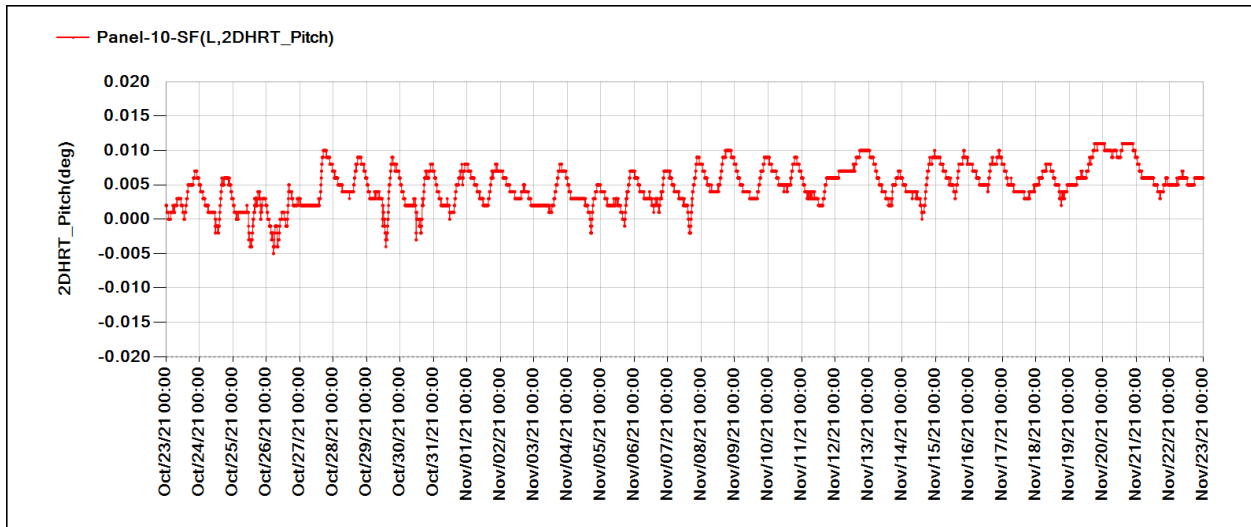
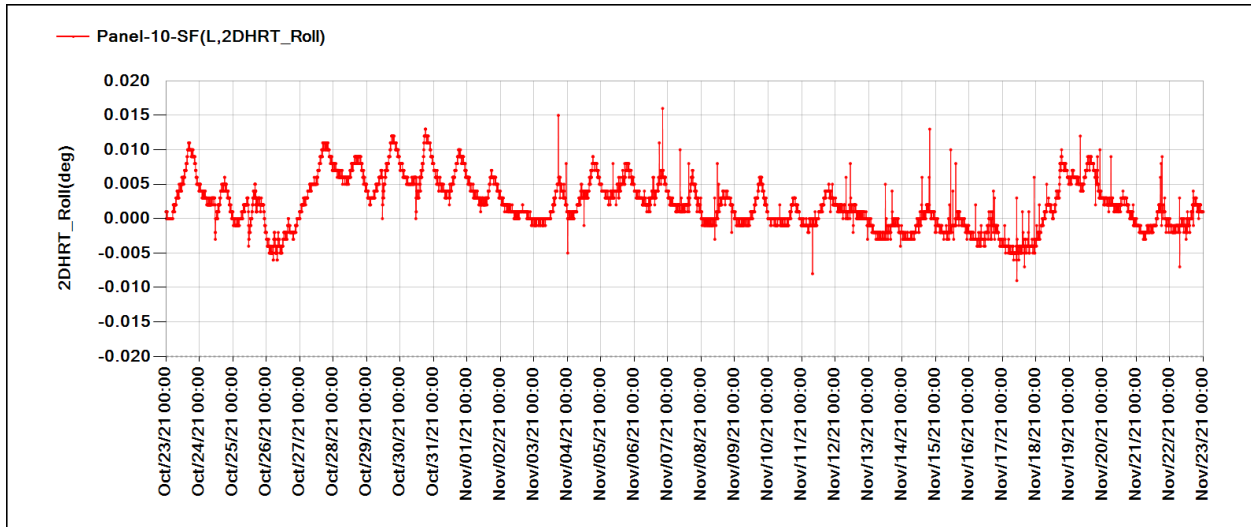
SenSpot™ is designed to operate maintenance-free for more than a decade. After installation, SenSpot™ does not need calibration, battery replacement, or any other maintenance for at least 10 years. Due to small size and lightweight, SenSpot™ sensors can be applied easily to as many critical spots on a structure as needed, with minimal installation effort.

Resensys sensors' ultra-low power usage allows short-term (during the construction) and long-term use (wireless health monitoring of Retaining Wall). This means that a key benefit of this power-efficiency is that short-term uses can be easily repeated multiple times without the need for battery replacement or intra-test charging if users wish to move the products from one location to another, or use the products for their own experimental tests. After tests, the same sensors can also be left on the structure for long-term/permanent use and continuous health monitoring. After installation, [SenSpot™](#) does not need battery replacement or any other maintenance during its entire service life.

Resensys' wireless system design is quick and easy to install because there is no additional wiring required. There is no need for communication infrastructure at the retaining wall location (infrastructure-less). This reduces installation cost and time, making Resensys solutions a cost-effective way for owners to get the quality data they need for retaining wall monitoring and decision-making.

[Resensys Wireless SenSpot™ sensors](#) are able to monitor structural/geotechnical quantities including inclination and ambient humidity/temperature in timber (different kind of woods), concrete, steel, and even composite materials under humid, rainy, snowy, icy and extreme weather conditions (-40°C to +65°C or -40°F to +150°F). The products are corrosion resistant and can withstand salty environments. They are small in size and lightweight.

[SenSpot™](#) data helps the stakeholders and engineers make informed decisions about the condition and slope of retaining wall faces to allow them to execute required actions (further geotechnical inspection or repair/retrofit within an appropriate response time, or validation that the repair is functioning as desired). Resensys products can provide early warning of imminent structural or geotechnical damage by their alarm feature and by alerting when pre-set data thresholds have been exceeded (by sending warning email/text/notification to corresponding authority). Resensys real time monitoring system can thus proactively alert authorities of potential effects of soil loads in advance of a possible damage or collapse. Moreover, by using the [SenSpot™](#) corresponding location data, authorities can find easily the affected area and evaluate its status by using structural/geotechnical quantities and temperature/humidity data.



High-resolution tilt measurements (2D-roll & pitch) in [SenScope™](#) for an installed HRT gauge (High-Resolution Tiltmeter) on a panel of a retaining wall



Resensys [Wireless Tilt SenSpot™ sensor](#) for measuring and monitoring tilt/inclination (in two directions) and temperature on the face of a Retaining Wall



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[Resensys Wireless SenSpot™ sensors](#) are easily installed on critical elements or sections of retaining walls (like retaining wall face) as determined by inspection, finite element modeling, previous test results, engineers' suggestions or authority's/client's needs. The sensors are mounted with adhesive or flange mounted depending on the application and element materials. A [SeniMax™](#) data acquisition unit is conveniently mounted nearby (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 health monitoring system, which can be used for retaining wall monitoring.

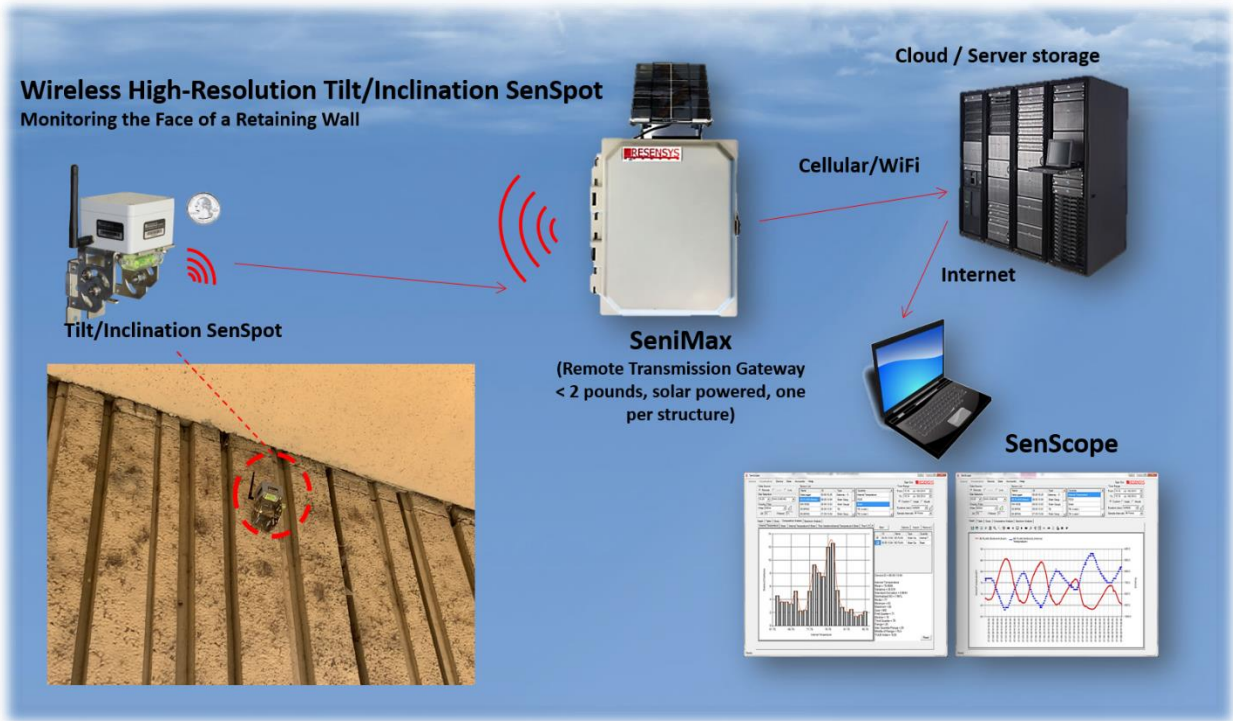


Illustration of Resensys SHM based on [SenSpot™](#) sensors for monitoring the Retaining Wall structures and inclination

Technical Specifications:

	<u>Wireless Tilt SenSpot™ sensor</u>
Size (Dimension)	-Transmitter Dimension: 79.6mm(3.13")x74.6mm(2.94") x 52mm(2.05") -Assembly Dimension:120.8mm (4.76") x 96.6mm (3.8")x149.9mm (5.9")
Weight	180 g (6.3 oz.)
Mounting	Flange-mount or adhesive tape
Accuracy (Resolution)	<ul style="list-style-type: none"> • Narrow Range HRT: $\leq 0.0003^\circ$ (5.2μrad) • Mid-Range HRT: $\leq 0.003^\circ$ (52μrad) • Regular tilt: 0.1$^\circ$
Measurement Range	<p>-Operating range:</p> <ul style="list-style-type: none"> • Narrow Range High Resolution Tilt: $\pm 0.5^\circ$ (with respect to vertical position) • Regular tilt: all directions <p>-Linear range:</p> <ul style="list-style-type: none"> • Narrow Range HRT: $\pm 1^\circ$ • Mid-Range HRT: $\pm 10^\circ$ <p>-Repeatability:</p> <ul style="list-style-type: none"> • Narrow Range HRT: $\leq 0.001^\circ$ (17.5μrad) • Regular Tilt: 1$^\circ$ <p>-Time constant: ≤ 1sec(High resolution tilt)</p>
Operating temperature	-40 $^\circ$ C to +65 $^\circ$ C (-40 $^\circ$ F to +150 $^\circ$ F)
Lifetime	battery life of 10 years (Ultra-low-power)
Installation Time	1-2 minutes
Complementary sensing	temperature, battery voltage, etc.
Communication range	1.0km(0.62mile)free space
Power source	Replaceable lithium-ion battery
Wireless communication	no wiring is required for data collection- IEEE 802.15.4