RESENSYS

Application Note

# Remote Roof Monitoring of Building (Warehouses, Facilities, etc.) under Snow Loads, Wind Gust, and Ponding

## using Resensys Wireless Strain Gauge SenSpot™ Sensors

**Keywords:** remote roof monitoring system, roof structural health monitoring, snow load monitoring sensors, roof deflection monitoring, wind gust monitoring, roof ponding monitoring, wireless roof monitoring solutions

**Wireless Roof Monitoring offers a comprehensive solution for assessing the structural integrity of roofs in various types of buildings, including warehouses and industrial facilities. Utilizing Resensys Wireless Strain Gauge SenSpot™ Sensors, this system delivers real-time and long-term insights to ensure safety and operational efficiency. Key monitoring capabilities include:**

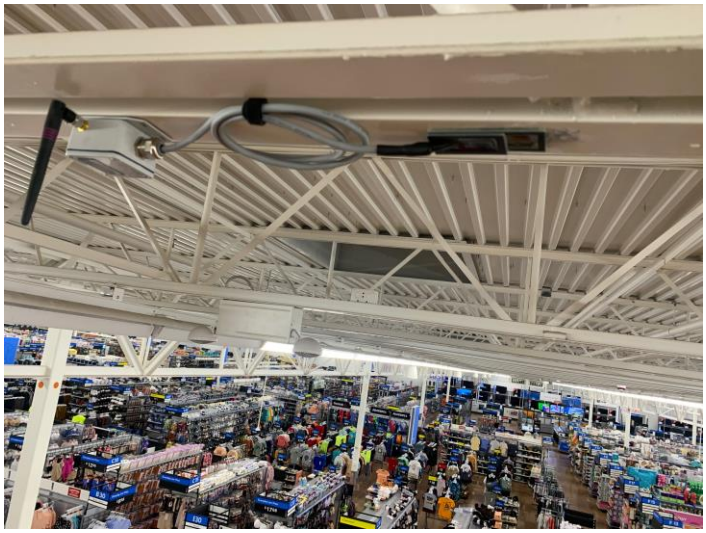
- **Stress, strain, and load monitoring on roofs and joists due to snow loads and ponding**
- **Deflection monitoring of roofs and joists to identify structural vulnerabilities**
- **Roof monitoring for wind gust-induced loads to prevent damage**

This application note highlights the deployment of **Resensys Wireless SenSpot™ Sensors** for remote roof monitoring. These sensors provide accurate, real-time data on snow loads, deflection, wind gust loads, and ponding, enabling proactive maintenance and ensuring structural safety in challenging environmental conditions.

**Roof's failure under snow loads**

**Left: Resensys wireless strain gauge (SenSpot™) used to monitor strain, stress, and deflection on joists; Right: a wireless SenSpot installed at a joist**

Flat-roofed buildings, such as warehouses, shopping malls, and airports located in regions prone to heavy snowfall, face a significant risk of damage and potential collapse under the weight of snow. Often, measuring snow accumulation proves to be an inadequate method for comprehending the risk of structural failure, as snow density can vary significantly based on its type (e.g., dry versus wet snow). Furthermore, other factors like wind and wind gusts could further elevate the risk of a roof's failure, particularly when it is already burdened with snow, ice, or ponding water.



**Wireless strain gauge SenSpot™ at a roof system**

For accurate and real time monitoring of roof systems, Resensys wireless strain gauge SenSpots™ monitor joists and joists girders. The sensor provides the following measurements:

- **Stress (and strain):** Most steel joists are designed for a maximum yield stress of 50 ksi. The measurement of stress in joists provides a good understanding of how close a joist is to the point of potential collapse.
- **Deflection:** In addition to stress, the sensors provide an accurate measure of deflection at the centers (mid-spans) due to factors like snow, ponding, and wind. Most joists can safely handle deflections of up to a few inches, depending on the type and length.
- **Wind or wind gust factor:** It is common for a snowstorm to be accompanied by strong winds or wind gusts. While snow causes slow-varying stress in the joists over time, the effect of wind or wind gusts is rapid and dynamic. By capturing up to 40-100 samples per second, Resensys wireless strain gauges can detect the effects of fast-varying strain caused by wind or wind gusts.

The effect of wind gusts is crucial for accurately assessing the risks of roof failure. While stress or deflection caused by snow or other loads might indicate a safe load condition, joists experience an elevated risk of failure when exposed to the effects of wind gusts. Most alternative methods of roof monitoring can not measure this increased risk of failure due to wind gusts. Resensys wireless strain gauges are the only products on the market that offer this capability.

To summarize, Resensys wireless strain gauges provide the following benefits when used for monitoring roofs under snow load:

- **Real time monitoring:** risk assessment based on measuring stress (load), strain, deflection
- **Notification:** email and text message alerts when joist deflection or stress (load) exceed limits
- **Wireless**: easy and fast to install
- **Break-down of load type:** provide separate effects of snow/ponding from the load caused by wind and wind gust.
- **Low maintenance sensor:** 10-year battery life sensors

The rest of this document illustrates details of using Resensys wireless strain gauges for monitoring roofs under snow, ponding, and wind loads.

## Example: Loading on 48LH10 open web joist.

The purpose of this example is to show how Resensys wireless strain gauge SenSpot™ can be used to monitor a building with **48LH10** steel joist. Assume that the end-to-end length of 85ft. In practice, the effective length (or design length) of the joist is commonly 1/3ft shorter considering the small end portions of the joist that rest on the support columns. This implies an effective length of 84.67ft. According to Steel Joist Institute (SJI) load tables, a linear load of 127 pounds per foot on this joist produced a deflection of L/360 = 84.67 ft/360 = 2.82 in. In addition, the stress corresponding to the L/360 deflection is 18.27 ksi. Considering the Young's Modulus of Elasticity of 29,000 ksi for steel, that stress corresponds to 629 micro-strain. This means that by setting a notification threshold at 629 micro-strain, building management personnel be notified when deflection/stress exceeds a critical limit.

This example is summarized in the table below. The calculation shows that in order to send a text message or email notification at when joist deflection exceeds 2.82 in (L/360), then the corresponding strain reading for the wireless gauge must be 629.9 micro-strain. Likewise, such threshold for L/240 (4.23in).

It must be noted that the system is capable of accepting multiple alert levels. For example, in this case, the L/360 deflection (629.90 micro-strain) can be configured as an early warning notification, while the L/240 (944.85 micro-strain) can be configured as an alert indicating a high risk of eminent failure.

| | |
|---|---|
| Joist Type | 48LH10 |
| Joist depth (in) | 48 |
| Joist Length (Ft) | 85 |
| Joist Design Length (Ft) | 84.67 |
| Load for L/360 deflection (pound per foot), according to American National Standard SJI 100 -2020 | 127 |
| L/360 deflection value (in) | 2.82 |
| Stress at center (KSI) for L/360 deflection (ksi) | 18.27 |

| | |
|---|---|
| **Strain at center for L/360 (or 2.82 in) deflection (micro-strain)** | **629.90** |
| **Strain at center for L/240 (or 4.23 in) deflection (microstrain)** | **944.85** |

As a last remark, the system produces the mentioned alert notifications when the combined effect of various loads (**e.g., snow, ice, ponding, and wind**) exceeds the configured threshold. This type of monitoring incorporates all factors and minimizes risk.

**Wireless Strain gauge SenSpot™ at a roof system of a building**

Wireless Strain SenSpot™ sensors are able to monitor strain and corresponding stress/loads occurring on flat roofs or roofs with inclination by installing them on the measurement nodes. These wireless gauges are able to monitor loads occurring on flat roofs or roofs with inclination. By measuring strain on the main roof girders, overall load on the building structure can be assessed, providing a real time picture of roof stress/ load conditions even when physical inspection is impossible due to icy or wet weather conditions.

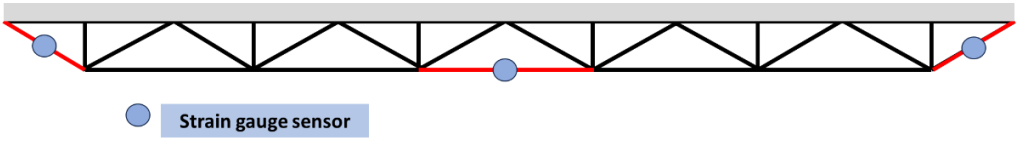
**Wireless Strain gauge SenSpot™**

**SeniMax™ Gateway at roof system of a building/warehouse for data acquisition**

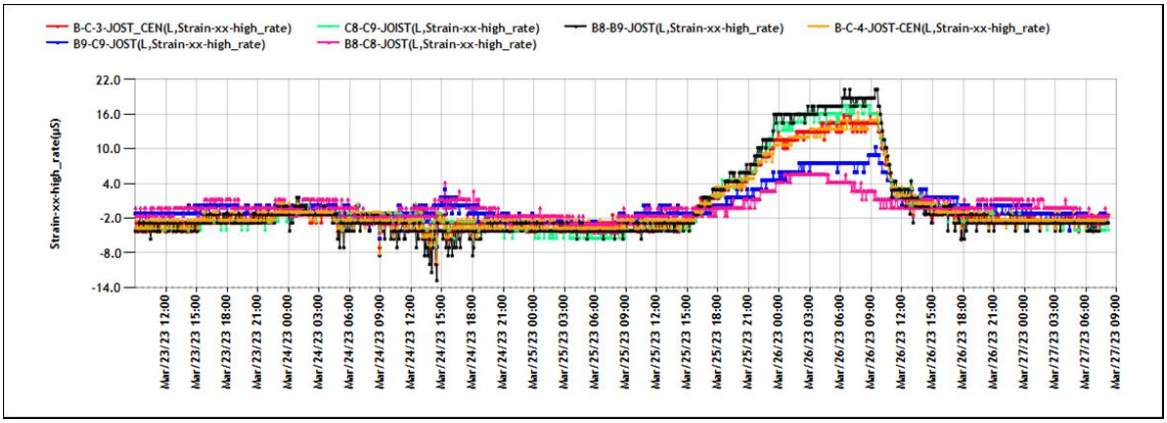
**Power Source: Solar Powered or Main Powered**

**Connectivity: Cellular or Ethernet**

The joists experience more stress in the middle of bottom chord and end web.




**Sample of suggested strain gauge sensor's locations on a steel joist of the roof system for a building**




**The strain responses of a snowfall in the area; the results show a clear response to load present on the rooftop with the greatest loads bearing down on structural members**

Figure below shows a picture of a practical Resensys Structural Health Monitoring (SHM) system, which can be used for remote roof monitoring under snow loads.


**Illustration of Resensys SHM diagram based on SenSpot™ sensors for monitoring the roof of large building or huge structures under snow loads**