Routine/ Contract Bridge Load Rating Validation

with SenSpot™ as test tool - Obtaining Strain Responses with Resensys Wireless Strain SenSpot™ Sensors

Load Rating is the safe live load that carries capacity of a highway bridge structure. Rating Factor (RF) is defined for concept of load rating and in terms of tonnage for a particular vehicle. Load rating is significant because different kind of vehicles have been used in the past for the design of bridges (e.g., H-15, HS20-44, HL-93, etc.) and some bridges are old, depreciated or become structurally deficient during their lifetime. All bridges are rated using a standard set of vehicles to have a reliable and constant summary of the load carrying capacities and it is called Legal Loads. So, the load rating is performed to ensure the safety of general public and traffic using highway bridge structures. Bridges that have inadequate load capacity are considered and posted for restricted loads.[1]

For conducting routine load rating of highway bridges, authorities can perform load rating based on the AASHTO LRFR (Load & Resistance Factor Rating). Routine Load Rating can be defined as vehicular live load capacity of a bridge by using as-built bridge plans or latest field inspection (NBIS). And, it is expressed as a Rating Factor (RF) or in tonnage for a particular vehicle as mentioned above.

Benefits of LRFR are uniform reliability in bridge analysis, more uniform posting levels, guidance for evaluation of overloads, procedures to ensure more consistency and uniformity in rating, optimal load factors for lower volume roads, introduction state-of-the-art technologies that could benefit existing bridges, and evaluation of bridge serviceability or service limit.

LRFR also results in bridge safety certification, provides data to support bridge rehabilitation or replacement needs and prioritization, and generates data that must be submitted to the National Bridge Inventory in order to comply with NBI Standards.

Thus, having routine, accurate and up to date Load Ratings are important to meet inspection and reporting requirements and ensuring that the correct bridge postings are achieved. They also allow infrastructure owners to make informed asset management decisions with regard to overall traffic pattern management, asset rehabilitation/ reinforcement to meet current or changing demands over time, and ensure that bridges can be safely operated and utilized.

Routine Load Rating can occur at several stages throughout a bridge's useful life; during design phase, during primary inventory inspection, and/or during the routine NBIS (National Bridge Inspections Standards Regulation) safety inspection of a bridge in the operation stage.

Routine/Contract Load Rating can also be conducted when changes in the live or dead loads on the structure occur, and/or when there is any physical change in structural members of the bridge (e.g. after retrofitting, maintenance operations or rehabilitation/ reinforcement activities). Routine Load Rating can also be helpful to ensure the safety of the bridge, particularly since natural events (such as a flood, earthquake or hurricane) or new construction activities in the area of bridge structure may cause damage or changes to the bridge or cause geophysical changes to the area of the bridge.

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[1] http://www.dot.state.oh.us/Divisions/Engineering/Structures/BridgeManagementSection/LRFR%20Seminar%20Handouts/Session3.pdf

Authorities and other bridge structure owners spend significant resources in validating and refining their load rating models and ensuring compliance with rule changes that could require re-rating of bridges based on updated requirements. Monitoring instruments are widely used during the load rating process.

The applicable, measurable and monitorable quantity in bridge routine load rating is strain.

The Resensys Wireless Strain SenSpot™ sensors are well-suited for bridge structure routine load rating due to their quick and easy installation, accurate, reliable, repeatable results, and the fact that there is no need for calibration in the field.

So, Resensys' wireless design reduces installation cost and time, making it a cost-effective way for owners to get the data they need. The ultra-low power usage allows multiple instances of short-term use (bridge routine load rating), which is ideal for load rating in the field. It also provides flexibility if authorities wish to keep the sensors on their structures permanently for long-term use (bridge structure health monitoring).

Resensys SenSpot™ sensors are able to monitor 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 Routine Load Rating solution comprises the following components:

- SenSpot™ sensors (for strain): which are attached to a bridge (Required number of sensors per structure, depending on design and routine load rating needs).
- 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 Strain SenSpot™ sensor installed on the bridge for bridge routine load rating

Resensys SenSpot™ sensors are easily placed/ installed on critical elements (girders, gusset plates, bearings, floorbeams, interior/exterior stringer, dead load consideration members, steel pier bent or truss members/connections) as determined by inspection, finite element modeling, load rating model or authority's/client's suggestion after major events (natural events or new construction activities in the area of structure). 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 (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 routine/ contract bridge load rating validation.

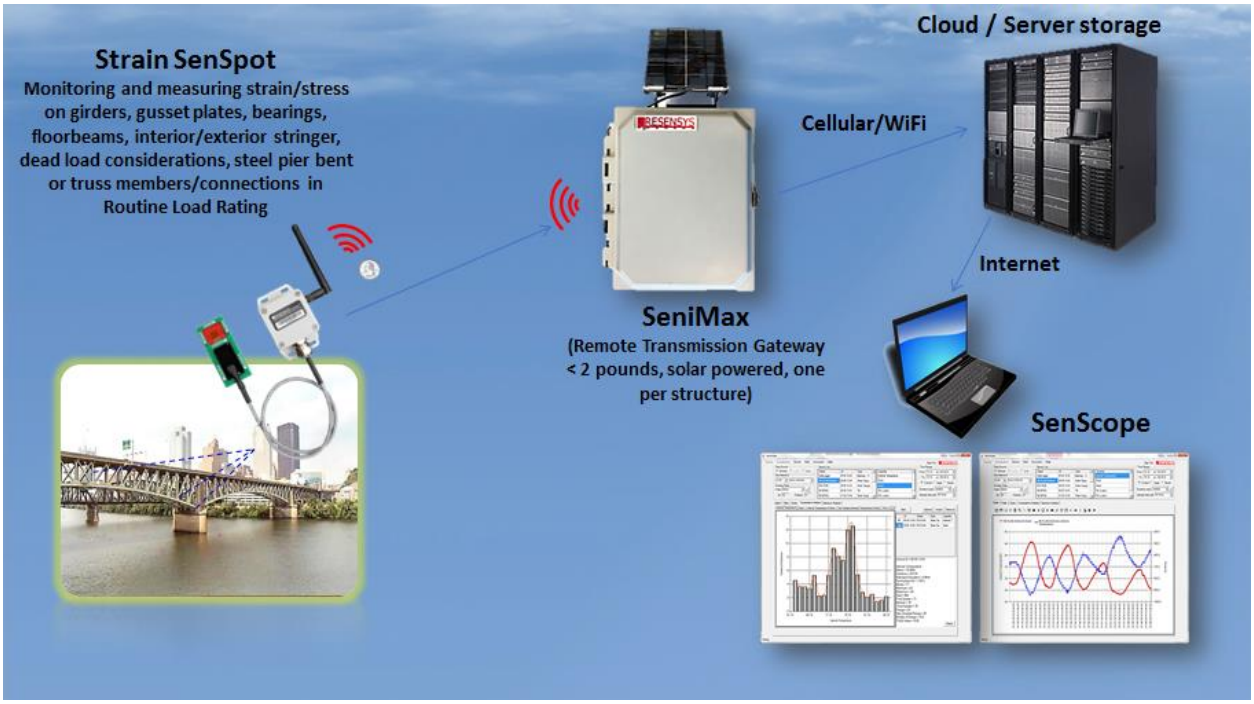


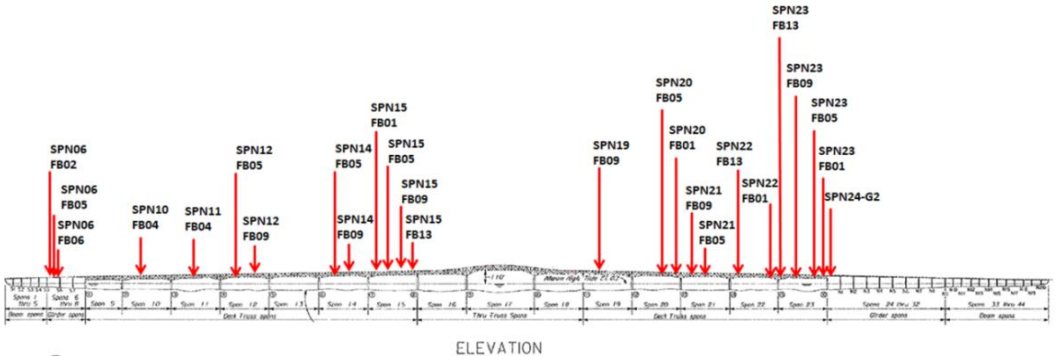
Illustration of Resensys SHM based on SenSpot™ sensors for bridge routine load rating

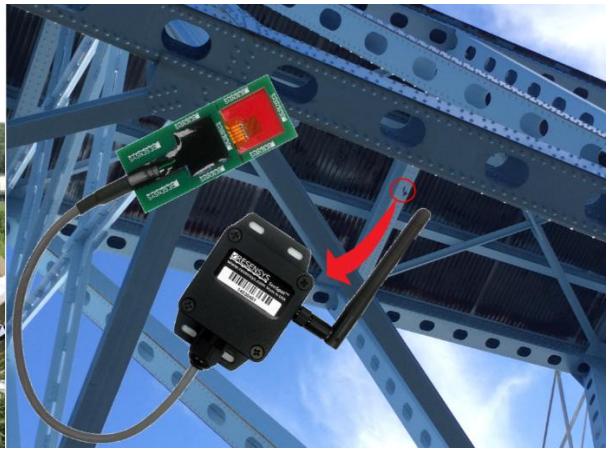
Load Testing Methodology: For load testing, one or two trucks (depending on bridge) with known weight are slowly driven over the bridge in different lanes and directions to maximize the loading on the gauged floor beams and girders. A comparison of the load effect of the moving truck on each of the locations where a strain SenSpot™ sensor is installed is provided to the authority/owner. The measured strains produced by trucks are then compared to the calculated stresses in these members generated from AASHTOWare's BrR load rating model. This information can then be used to see if the load rating is accurately modeling the performance of the members.

Frequently, load testing activities allow short-term load testing data to be gathered. Since Resensys' long-life system works continuously from the time of installation, and alert systems monitor any change in the strain on girders, bearings, gusset plates and truss members of the bridge for as long as the sensors are left in place, some owners choose to leave the sensors in place after load testing. The continuous data from these sensors can be generated as a routine (annually, monthly or custom) report for the district showing the peak strains that are produced by standard traffic utilizing this bridge. Due to the ultra-low power usage of Resensys' products, this data and reporting can continue virtually maintenance-free for up to 10 years allowing future analysis and testing without the need for additional set-up.

A breakthrough method for fast and accurate bridge load rating using Resensys Wireless Strain SenSpot™ is:

1- Attach adhesive mount Wireless Strain SenSpots™ to critical members (e.g., beams, girders, truss members, gussets);
2- Drive truck of known weight (steer axle, drive tandem axle and gross weight) over the bridge;
3- Calculate load carrying capacity using the responses of the members.





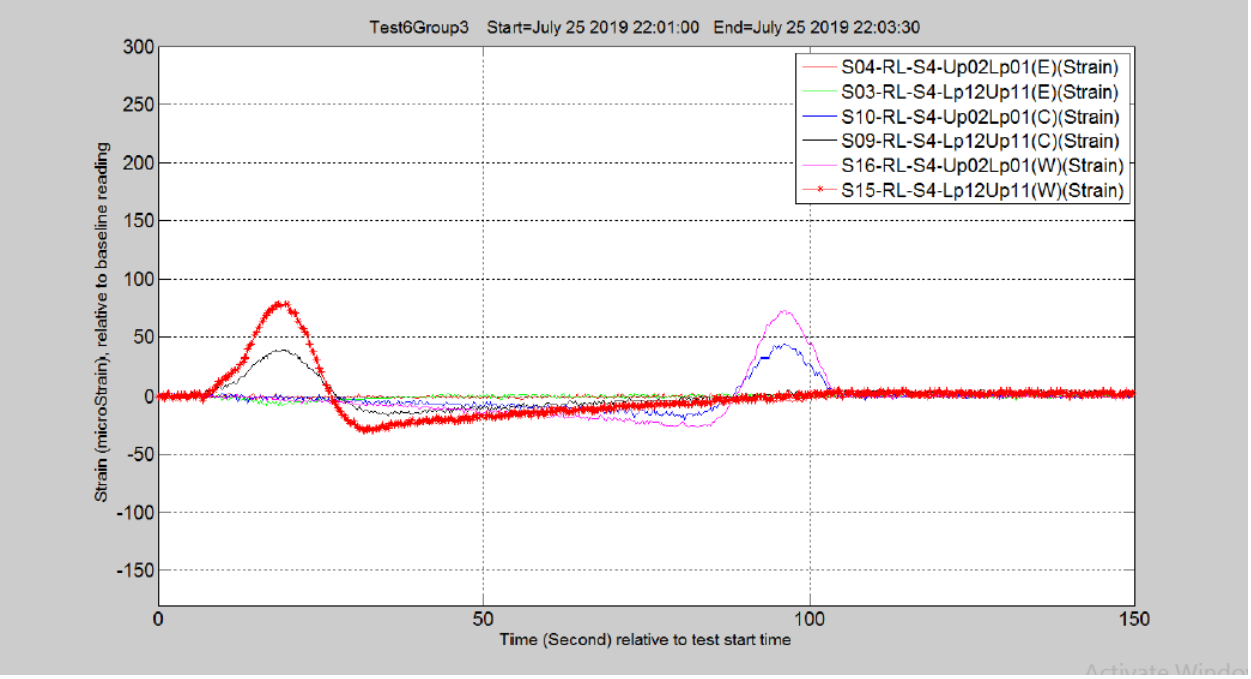
SenSpot™ as a tool for truck-test bridge routine load rating

Technical Note: For the purpose of calculating and presenting results, the following method has been used.

Baseline reading: is calculated as the average of the ten strain readings of a strain gauge right before the truck passes over the bridge.

Strain increase: for each device, strain increase is calculated as the difference between the maximum and the baseline.

Finally, small strain variations of about ±1 microstrain from one test to another are result of sensor resolution and the effect of small random vibrations in the structure at the time that the truck was passing over.



Strain peaks on various members caused by test truck

Technical Specifications:

	Wireless Strain SenSpot™ sensor
Size (Dimension)	76.2mm (3") x 33.4mm (1.3") x10mm (0.4")
Weight	147g (5.2 oz.)
Mounting	- Self-adhesive, no drilling is required (e.g. steel) -Flange-mount, drilling is required (e.g. concrete)
Accuracy (Resolution)	2μStrain
Operating temperature	-40°Cto +65°C (-40 °F to +150°F)
Lifetime	Minimum expected life without battery replacement is 3 years (Ultra-low-power)
Installation Time	1-2 minutes
Complementary sensing	Temperature, battery voltage
Communication range	1.0km(0.62mile)free space
Power source	Replaceable lithium ion battery
Wireless communication	No wiring needed for deploying the system- IEEE 802.15.4
(Optional) High rate data transmission triggered by sudden strain changes	- A balance between power consumption and performance. - Perfect for recording the waveform of a sudden strain change. - The triggering threshold is adjustable from 16μStrain to 512μStrain; the sampling interval can be changed from 25ms to 200ms.