Advanced Bridge Inspection Techniques
Structural Performance Monitoring and Assessment –

STRAAM Group performs an advanced service that is designed to complement bridge inspections. We use unique advanced technology and proprietary algorithms to rapidly capture the dynamic response of structures. The information is used to measure and record the structure's condition and to use the information to assess the structure's performance.

During the inspection process, the STRAAM Group equipment is placed on the bridge at specific locations and captures dynamic information. The system can be set up in minutes by the inspection team prior to beginning their regular bridge inspection. After the inspection, the equipment is removed. The dynamic signature processed from the captured data provides the structure's dynamic response which is a record of its condition at that time. The information can be used in analysis to provide objective information regarding the performance of the structure and its foundation.

Dynamic response information adds value by providing:

1) The raw acceleration levels that the structure sustains to quantify the impact and movements the structure experiences. Variations in this information can help identify weaknesses or problems with the structure.
2) Frequencies of resonance and damping response information which provides an objective measure of the structures stiffness and energy dissipation mechanisms.
3) A measure of the behavior of the foundation and soil conditions. This information can uncover poor foundations conditions and potential scour locations.
4) Objective information which can be used to calibrate a finite element model to compare its current condition to its original design condition. Also the dynamic signature information can be used to calculate soil spring constants for the FE model.

Below is some detail regarding the valuable information that is generated by performing dynamic performance monitoring during the inspection process.

Vibration Intensity level – The vibration intensity level will be captured to establish what vibration levels the structure experiences. For specific structures, this information can uncover areas which have lost strength reflected through high vibration levels. Also, this information can be compared over time to look for changes in the response. This is specifically valuable for rail bridges.

Dynamic Signature information – The advanced instruments used by STRAAM to gather vibration intensity information also capture the structures dynamic response. Through the use of advanced algorithms, we process the acceleration data into the Dynamic Signature of the structure. This signature will define the structures performance. The Dynamic Signature also provides a measure of the structures condition. The graph to the right shows the Dynamic Signature of a structure. It defines the frequencies of resonance and damping response of the structure. In this graph a low frequency response (circled) likely indicates a problem with the structure. This could develop into a failure mode which would be recognized by a decrease in frequency and/or increase in amplitude. Dynamic measurements can uncover weaknesses that cannot be seen through inspection. Follow up measurements can be compared to the baseline signature to look for changes. When performing real-time monitoring of structures under construction, we update the dynamic signature continuously to track changes to the structure.

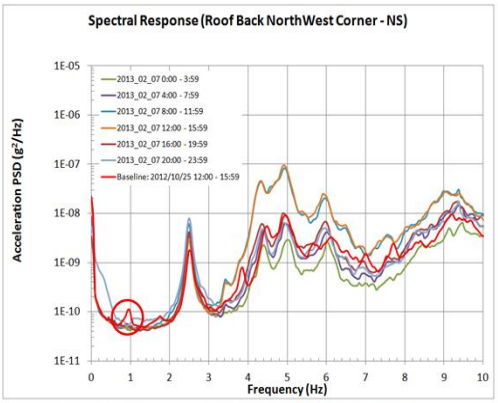
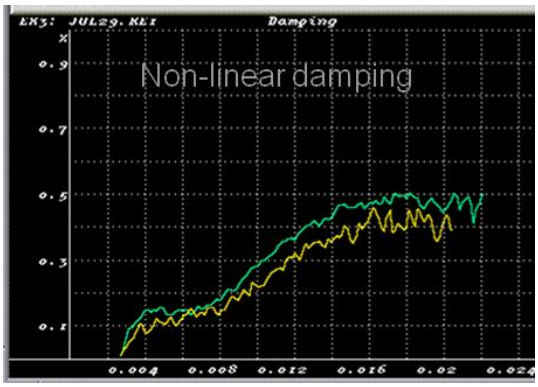


Figure 9: Spectral Response recorded from Roof Back sensor in the N/S direction
Comparison between January 6th and February 7th

RANDEC damping algorithm – The non-linear damping response of a structure is an important characteristic that details how energy is dissipated within the system. It is also related to the structures elastic limit and can be used to extrapolate capacity of a structure. We provide a direct measure of the structures non-linear damping response as measured on the bridge using the Random Decrement Algorithm (RANDEC). The classic damping curve (shown on the right in green) is the damping response of the structure at a specific measured structural resonance. As depicted, the curve generally has a low amplitude plateau, increases with the increase in amplitude to a high amplitude plateau. As the amplitude increases, more energy is dissipated within the matrix of the structure and through soil interaction thus yielding a higher damping value. The rise of the slope can be extrapolated to the structures elastic limit. Additionally, as damage occurs within the structure, smaller cracks degrade into larger cracks, dissipating more energy. The yellow curve is a measurement of damping on the same structure soon after damage was sustained and reflects a change to the original (green) curve. When creating a 'Baseline Dynamic Signature' a measurement of the damping response at various levels of energy is captured providing a record of this characteristic which can be used for future comparison. It is also effective in identifying specific flaws in the structure.



In depth analysis – Further processing of the data can be used to calibrate Finite Element Models to provide a detailed understanding of how a structure performs and to perform load ratings. Anomalies in the response can be viewed through the FE model providing an understanding of the structures capacity based on the accurate field measurements. The frequencies of resonance of a structure are directly related to its load carrying capacity.

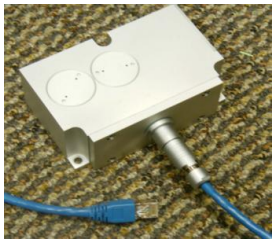
Long term monitoring – If problems are discovered, providing continuous monitoring can be a way of assuring that a structure is safe for the traveling public. Changes to the structure which can not a seen through visual inspection, can cause an obvious change in the dynamic signature when the proper instruments are deployed.

Field Installation

The equipment (shown below) is very simple to install and can be used for temporary or permanent installations. During the inspection, the accelerometers are quickly secured with clamps to the structure at predetermined locations. The accelerometers are then wired to the SKG with cables that are spooled for quick deployment. After placing the equipment, the inspector simply pushes the START button to start the recording of data onto STRAAM's Structurocardiograph - SKG. If needed, the SKG can be programmed to process the data for immediate detailed information for the field crew.

The SKG can also be connected to the internet for immediate uploading of data to the STRAAM CENTRAL Web Portal. The structure specific information can be posted on STRAAM CENTRAL in graph form or in a spread sheet to provider immediate comparison before the inspection is completed, if needed.

Equipment and Web Portal

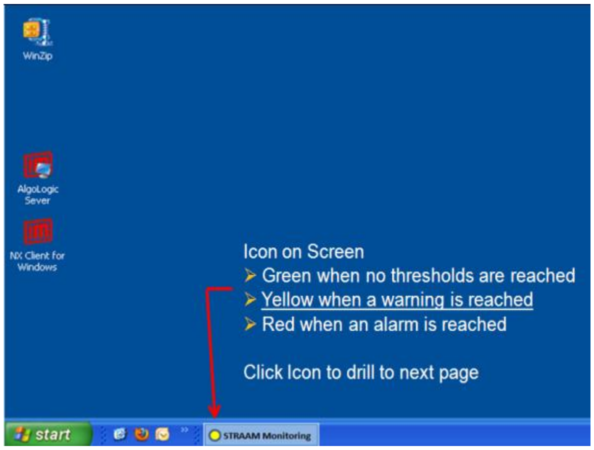


Accelerometers – STRAAM uses the most advanced, extremely sensitive accelerometers allowing us to capture high and low amplitude vibrations which are processed into a complete dynamic profile of the structure for analysis.

Structuro-cardiograph - **SKG** – STRAAM's data collection and processing system that captures dynamic measurements. The SKG will be installed on the bridge and are connected to the internet for the transfer of data to a secure site. It has an internal battery so that no external power requirements are needed for up to 6 hours.

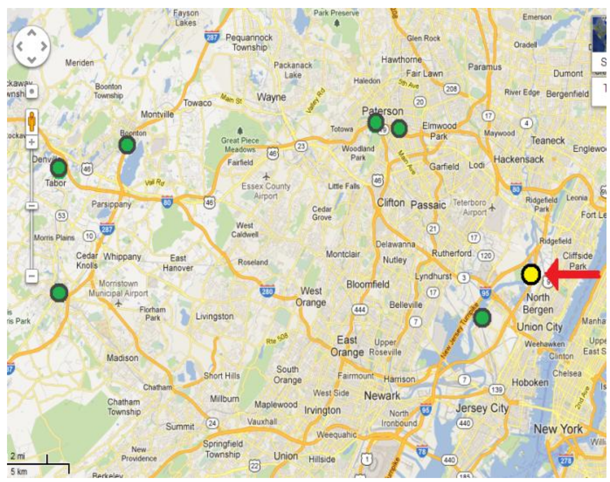
STRAAM CENTRAL – STRAAM's real-time Web portal**.** All information will be uploaded to STRAAM CENTRAL. The interactive site is a secure location where the information can be presented for real-time viewing. Each sensor will be shown in a graphic display which has pre-set thresholds and alarms.

STRAAM Central is designed to be easily navigated by users to show current and historical information with the click of a mouse.



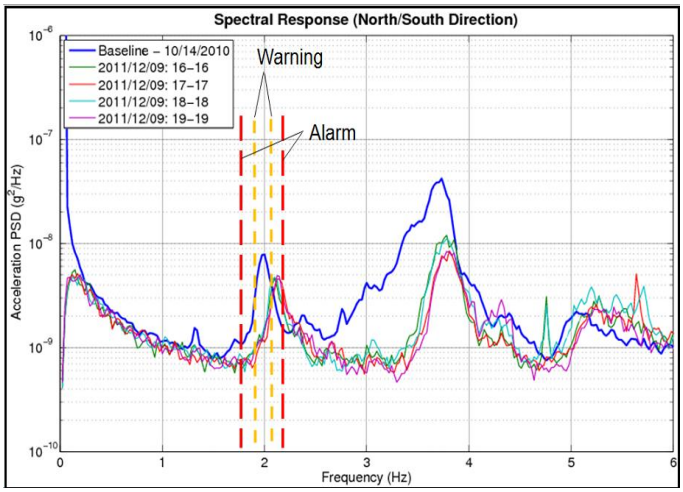
Screen 1, minimized - If a threshold is exceeded, the client, engineer or STRAAM team will know immediately by getting an email or text message sent to them. Additionally the multi-layer website will provide notice by changing color from Green (safe) to yellow (warning) on the minimized window. Simply clicking the yellow Icon will take the user to the next page. A red icon would indicate the alarm status has been exceeded.

Screen 2, Map page - The second page of the STRAAM CENTRAL is a map of all of the structures being monitored for the client. Each circle represents a structure that is being monitored, with a green, yellow or red threshold status. This gives a visual display of the status of every structure being monitored by STRAAM CENTRAL. By clicking the yellow icon, you will move to the specific structure being monitored.



Screen 3, Structure page – The map page links directly to the specific structure where every location and status is presented. An exceedance of the threshold is indicated with a change in color. By clicking it, the user will link directly to the data page showing real-time results for each sensor.

Screen 4, Data page – the real-time response of each sensor is displayed showing current measurements as well as the threshold limits. Additionally, the user has the ability to quickly look at historical data for the sensors to compare previous results with current measurements.



Point	Dir	Freq. (Hz)	Tension (Kips)	Point	Dir	Freq.(Hz)	Tension (Kips)
1	X	3.99	1030	5	X	3.95	1010
	Y	3.98	1025		Y	3.96	1015
2	X	3.97	1020	6	X	3.68	825
	Y	3.96	1015		Y	3.67	820
3	X	3.76	915	7	X	3.98	1025
	Y	3.77	920		Y	3.98	1025
4	X	3.96	1015	8	X	3.97	1020
	Y	3.98	1025		Y	3.97	1020

Spread sheet – If applicable, the processed response information can be automatically put into a spread sheet with previous historical information to provide the owner with a comparison of previous data to quickly understand if the structure has and trends which could be of concern.