SEQUOIA

SMART SOLUTIONS FOR VIBRATION MONITORING

Application Note

A simple instrument to evaluate structural cables tension.

ABSTRACT

The construction of structures covering progressively longer spans and employing cables as supporting elements has increased worldwide, leading to very suitable applications in bridges, roofs and special structures. An example of cable-stayed bridge is reported in Figure 1. These structures are generally characterized by complex structural behaviour, with significant geometric nonlinearity, high deflections under service loads, a high number of vibration modes closely spaced in frequency, several of which of local nature and subjected to vibrations induced by winds, traffic and human actions.

In this light, the structural behaviour of these structures is influenced by the level of cable stress. This feature makes their construction complex, demanding the accurate installation of cable pre-stress. Furthermore, this often determines the need for assessment of cable force during and after construction and it is particularly relevant for cable-stayed bridges and roof structures.

Figure 1: Calatrava bridge, Reggio Emilia (Italy).

A normal cable force state of a suspension bridge is extremely vital to the bridge safety. For cable force monitoring of suspension bridges, using an indirect measurement with FastTracer would not destroy the bridge's original structure and also meet engineering requirements.

The tendency of cable structures to vibrations and the frequent observation of a reduced service life of these structures and members have motivated the interest in assessing the corresponding structural condition by means of the dynamic monitoring.

More than other type of structure, suspension and cable-stayed bridges have been the object of dedicated monitoring systems, enabling the characterization of the response and the identification of the cable tension force is the main objective in these structural health monitoring systems.

According to features of bridge cables, a cable force health monitoring scheme is proposed based on string vibration and FastTracer sensing.

BACKGROUND

RELATION BETWEEN CABLE TENSION AND CABLE EIGEN FREQUENCY

The identification of cable force based on vibration measurements is derived from the relation between the cable vibrating frequency and the installed force. This relation results from the establishment of the dynamic equilibrium equation of the cable idealised as tensioned beam under different end conditions. Accordingly, a simple supported cable with uniformly distributed mass per unit length m and length l, bending stiffness EI, tensioned with a force T, vibrates with a natural frequency of i^{th} order f_{si} defined by:

$$\left(\frac{f_{si}}{i}\right)^2 = \frac{1}{4ml^2}T + \frac{r^2\pi^2}{4ml^4}EI$$
(1)

Therefore, if the mechanical characteristics of the cable are know the measurement of one cable frequency can provide one estimate of the cable force.

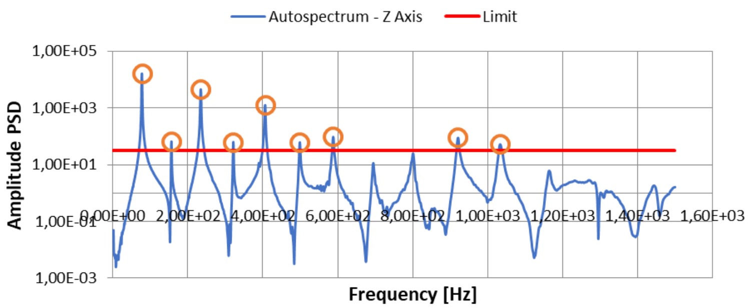
WHAT TO MEASURE

In an attempt to obtain sufficient accuracy in the identification phase, free vibration tests are normally required during which cables are manually or mechanically excited. For long span cables excitation is more effective at a sufficient distance from the cable anchorage. An example of bridge cable test is depicted in Figure 3, in which a crane was adopted to manually excite the cables at a height of about 10 m.

Figure 2: Manual excitation of cables for identification of bridge cable.

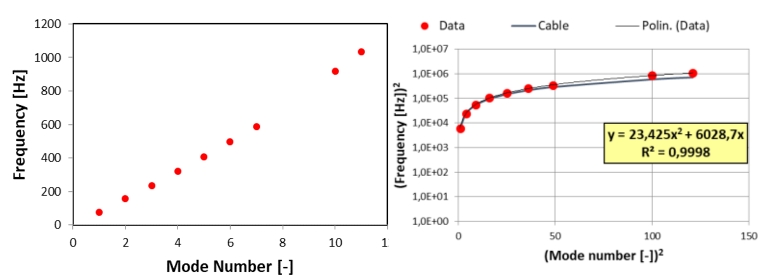
COMPUTATIONAL PROCEDURE

Therefore, to calculate the final tension force T, the Fast Fourier Transform (FFT) is derived from FTAnalyzer. The latter software is associated at the FastTracer system.



Next, the obtained results are depicted in a graph, that shows the variation of frequency respect to the mode number. According to the Equation (1) and the regression curve of the vibrational data measured, the final value of the cable force is computed.

This procedure is automatically performed by an Excel modulus developed by Sequoia IT, which is accessible to all from the site www.sequoia.it.



FTAnalyzer software supports a wide range of vibration analyses (which can be conducted simultaneously) for the assessment, understanding, and analyses of relevant vibration phenomena.
The measurement reading can be readily exported to Excel, for reporting or analysis purposes.

FAST*TRACER* FEATURES

HARDWARE

Fast*Tracer* is a digital tri-axial sensor based on MEMS technology. It can be easily connected to the PC with the supplied USB cable turning it into a simple and powerful hand held vibration analyzer:

SPECIFICATIONS:	
Sensor	Tri-axial, MEMS, Digital
Full Range	±5 g (option ±2 g, ±18 g)
Frequency Range	0 ÷ 2500 Hz
Protection grade	IP67
Dimension	30 x 55.5 x 15 mm
Weight	55 g
Shock Resistance	10.000 g

SOFTWARE

The FTAnalyzer software allows several real-time and post processing vibrations analysis:

- ✓ Time Signal Analysis
- ✓ RMS evaluation in conformity with ISO 10816-3 standard
- ✓ Spectral Analysis in term of acceleration, velocity and displacement
- ✓ Bump Testing for resonance frequency evaluation

Further the software can record long term time history and provide direct integration with Excel for data visualization and reporting

OPTIONS

The sensor can be easily connected to the PC using the standard 3m cable supplied. As options, several extension cables are available with max length up to 30 m.

For hard to reach points a Wifi Communication kit is available as well.