# Long-term Dynamic Monitoring of an Iron Arch Bridge

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## Summary

A multi-channel dynamic monitoring system has been recently installed in a centenary iron arch bridge that crosses the Adda river about 50 km far from Milan: the San Michele bridge. The paper describes the monitoring system and the signal processing tools developed in LabVIEW for automatic processing of the collected data. The implemented routines include the automated identification of the bridge's modal parameters by using the Frequency Domain Decomposition method. The application of this procedure to the data collected in the first weeks of monitoring turned out to provide a clear and robust tracking of more than 20 natural frequencies.

**Keywords:** Arch bridge; automated modal identification; continuous dynamic monitoring; frequency domain decomposition; iron; operational modal analysis.

## 1. Introduction

The San Michele bridge over the Adda river at Paderno, built between 1887 and 1889, is one of the masterpieces of XIX century iron architecture and a symbol of Italian industrial archaeology heritage [1]-[2]. The historic bridge, protected by the Italian Ministry of Cultural Heritage since 1980, shares its structural architecture with similar iron arch bridges built in Europe at the time, such as the Garabit viaduct in France (1884, Eiffel and Boyer), the Maria Pia (1877, Eiffel and Seyrig) and the Dom Luiz I (1885, Seyrig) bridges, over the Douro river in Porto.

The iron bridge (Fig. 1) consists of an upper truss-box girder, 266,0 m long, and two couples of parabolic trussed arches, transversally connected by cross-beams and bracing elements; the resulting arch structure has clear span of 150,0 m and rise of 37,5 m.

In order to address a Structural Health Monitoring (SHM) program of the bridge − that is still used as a combined road and railway bridge − a series of dynamic tests was performed in operational conditions between June 2009 and March 2010 [3]-[4]. The modal parameters identified in those tests demonstrated that:

(a) the bridge generally exhibits low values of the damping ratios ($\zeta_i < 1\%$);
(b) the vertical bending modes exhibit non-symmetric modal deflections on the upstream and downstream sides of the deck. Since the original design drawings and all documents available on the refurbishments do not show any significant lack of symmetry between the two sides of the bridge, the mode shapes uneven − revealing a different stiffness of the downstream and upstream sides − is conceivably related with the different state of preservation of the structural elements on the two sides;
(c) under the service loads (road traffic), the natural frequencies of vertical bending modes exhibit slight variations, possibly depending on the excitation/response level;
(d) the mode shapes in the transverse direction reveal a significant relative deformability of the two decks of the truss-box girder.

Since operational modal testing and analysis turned out to be effective tools for the SHM of the bridge, a joint research started between the Italian Railway Authority (RFI) − the main owner of the infrastructure − and the VIBLAB (Laboratory of Vibrations and Dynamic Monitoring of Structures) of Politecnico di Milano, including the installation of a dynamic monitoring system on the railway

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