BRIDGE DYNAMIC MONITORING

Introduction

Monitoring of structure movements and vibrations (bridges, buildings, monuments, towers etc.) is an increasingly important task for today's construction engineers. **IBIS-S** introduces a totally new solution in this field of application, with many advantages over traditional instruments for both static and dynamic monitoring:

- remote sensing at a distance of up to 1 km
- displacement accuracy up to 1/100 mm
- real-time one-dimensional simultaneous mapping of all displacement detected on the structure
- fast installation and operation
- the same instrument can be used for static and dynamic monitoring
- structure vibration sampling up to 100 Hz
- operates day-night, in all weather conditions

Fig. 1: IBIS-S

Hereinafter the results from an investigation performed on a bridge are given as an example of dynamic structural monitoring. The experimental results consist of:

- visualisation of the displacement of some specific points on the bridge
- identification of the resonance frequencies of the structure
- identification of modal shapes

This experimental campaign has been carried out thanks to the collaboration with the Department of Structural Engineering at Politecnico di Milano who has compared IBIS-S results with the accelerometer system results used simultaneously alongside IBIS-S.

Measure description

One of the advantages of IBIS-S is that it simultaneously measures the displacements of all the scenario illuminated by the antenna beam providing a continuous mapping of the static and dynamic displacements of the entire structure.

In order to exploit this key feature for bridge monitoring, the best position to install the sensor is under the bridge arch so that IBIS-S antenna beam can cover the entire structure, as illustrated in the figure below.

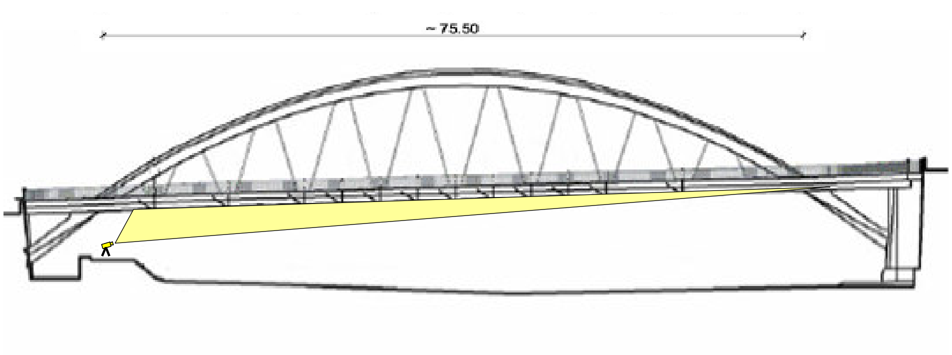


Fig. 2: Installation diagram

In the described measure IBIS-S was installed under the arch of the bridge at a vertical distance of about 4m.

From this position IBIS-S illuminated the bridge arch from 7m to 70m far.

The system was configured with the following operational parameters:

- maximum range: 85m
- distance resolution: 50cm
- sampling frequency: 100Hz

In order to perform a direct comparison between the data acquired with IBIS-S and those acquired by the accelerometers, 12 radar reflectors were installed (*corner reflectors*) in correspondence with each accelerometer. The use of corners was necessary to accurately identify the points where the accelerometers were installed.

Fig. 3: IBIS-S installation

The following figure shows the image of the bridge acquired by IBIS-S: the figure shows the 12 points corresponding to the corner reflectors (CR) on which the analysis will be carried out.

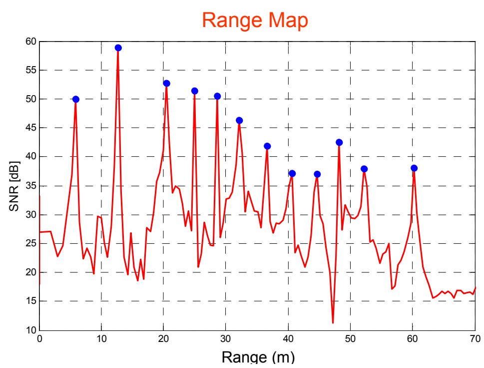
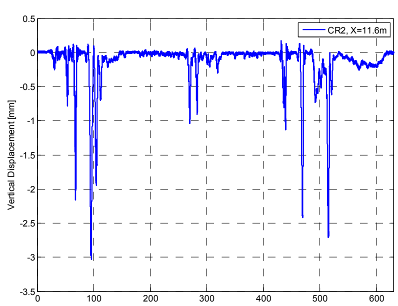


Fig. 4: Distance profile (radar image)

Results - Displacement data

AS IBIS-S raw data is the displacement of the targets belonging to the illuminated scenario, the following figures show the displacement data for the entire duration of the measure and for a temporal zoom of 30 seconds of 4 of the 12 installed CR. These CR were positioned at 11.6, 24, 31.4 and 59.5 m far from IBIS-S along the bridge.



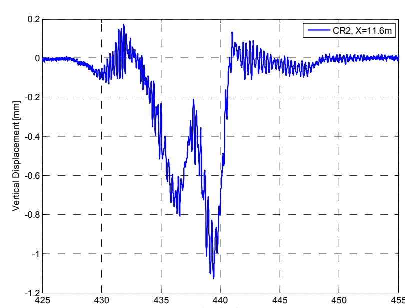


Fig. 5: CR 1 displacement. Entire measure (left), 30sec measure (right)

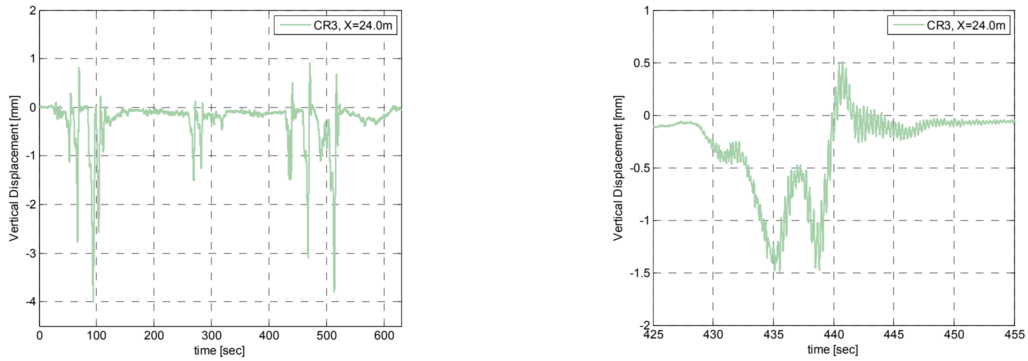


Fig. 6: CR 3 displacement. Entire measure (left), 30sec measure (right)

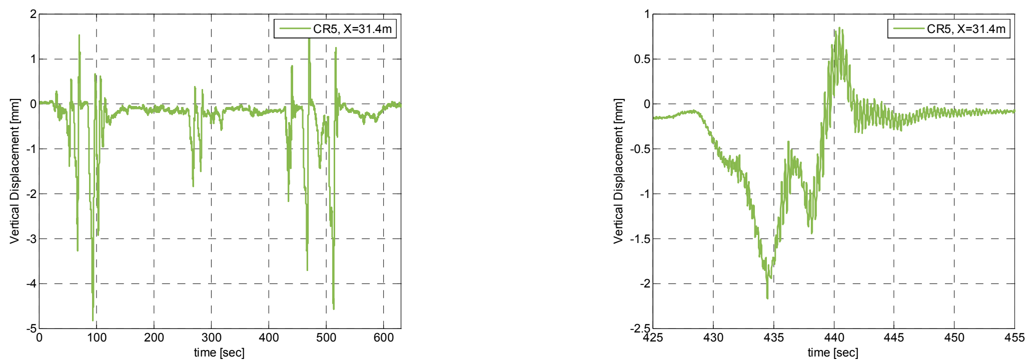


Fig. 7: CR 5 displacement. Entire measure (left), 30sec measure (right)

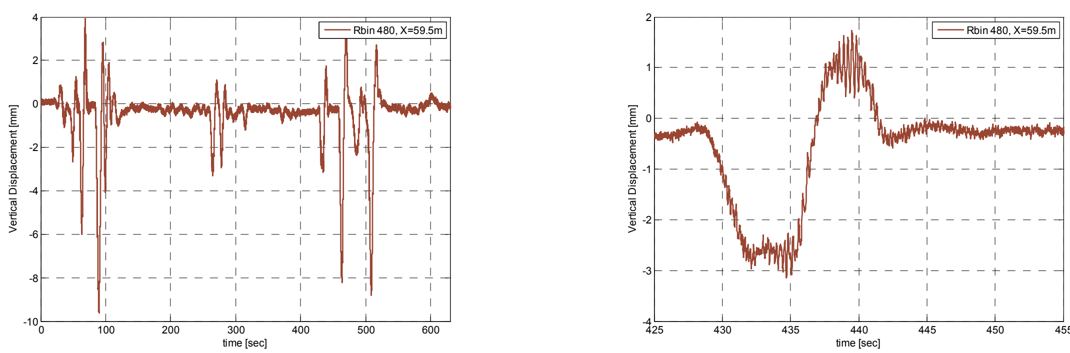


Fig. 8: CR 11 displacement. Entire measure (left), 30sec measure (right)

By the observation of the previous images it is possible to infer the good quality of the displacement signal even at far distances.

In order to validate IBIS-S collected data, a comparison between IBIS-S data and accelerometer system data was performed. The following figures show the comparison of the velocity of a point of the bridge 8m far from IBIS-S measured by the two acquisition systems.

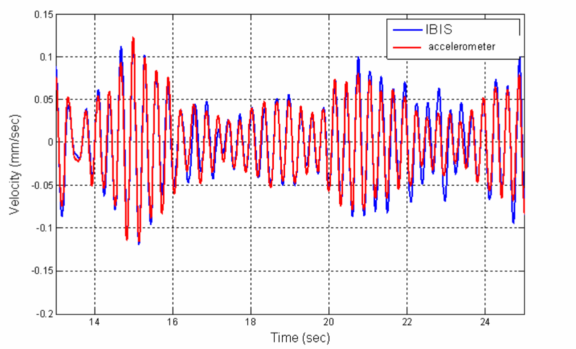


Fig. 9: Comparison of velocity filtered over the first bending mode

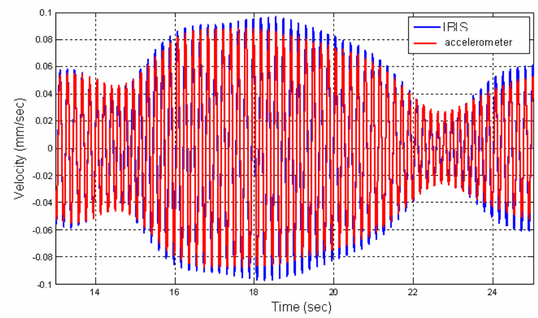


Fig. 10: Comparison of displacement filtered on the last bending mode

The figures show the excellent correspondence between the two measurements over time.

Results – Frequency and modal analysis

Results of data processing in terms of extracting the resonance frequencies of the bridge are shown in the following figure, including:

- the frequency spectrum of the structure derived from the IBIS data, coloured blue
- the frequency spectrum of the structure derived from the accelerometers, coloured red.

An excellent agreement can be seen between the two spectrums.

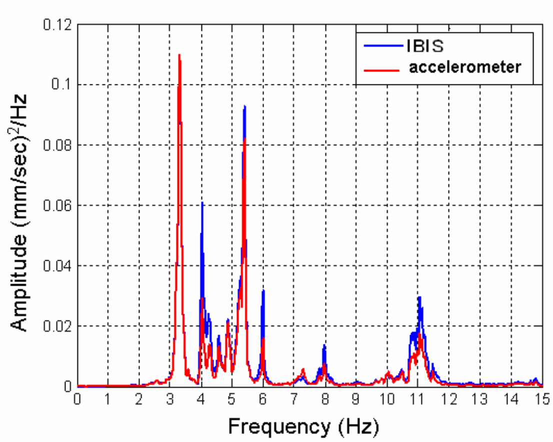


Fig. 11: Autospectrum comparison

f1	3.44Hz	f5	5.96Hz
f2	4.02Hz	f6	7.81Hz
f3	4.81Hz	f7	10.64Hz
f4	5.25Hz	f8	10.78Hz

Tab. 1: IBIS-S derived resonance frequencies

Analysis of the data acquired by IBIS permits all the resonance frequencies of the bridge identified by the accelerometer system to be derived as shown in Tab. 1.

A complete modal analysis of the bridge includes even the determination of the bridge modal shape for the different resonance frequencies. Hereinafter the comparison of the bridge modal shape, derived from IBIS-S data and accelerometer data, for the frequency f=3.44Hz:

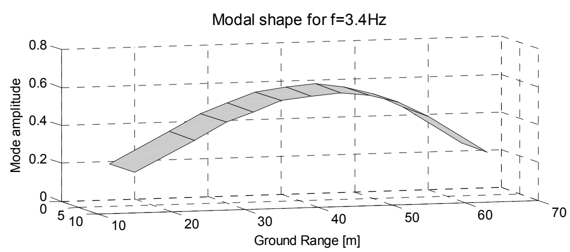


Fig. 12: Modal shape for f=3.4Hz (IBIS-S data)

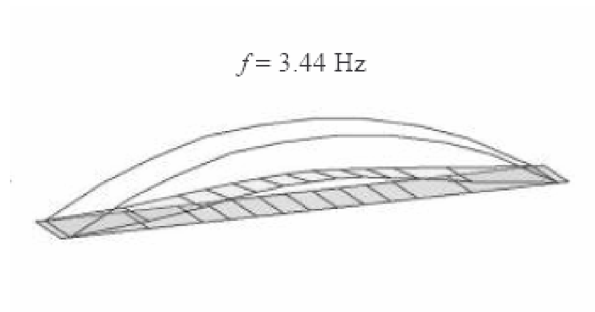


Fig. 13: Modal shape for f=3.4Hz (accelerometer data)

It easy to see that the two modal shapes are similar and comparable.

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