# Operational Modal Analysis

## On a Highway bridge for model updating

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*"When using the analysis of vibration measurements as a tool for health monitoring of bridges, the problem arises of separating abnormal changes from normal changes in the dynamic behaviour. Normal changes are caused by varying environmental conditions such as humidity, wind and most important, temperature. In the frame of the European SIMCES-project, the Z24-bridge in Switzerland was monitored during almost one year before it was artificially damaged; what makes it an excellent object to study methods that try to filter out the environmental influences".*

From Bart Peeters
KATHOLIEKE UNIVERSITEIT LEUVEN

## Introduction

Dynamic characterization of civil engineering structures becomes increasingly important for dynamic response prediction, finite element model updating, structural health monitoring, as well as passive and active vibration control of the high/middle-rise buildings, towers, long-span bridges, etc.

Civil engineering structures can be adequately excited by non-measurable ambient, or natural, excitation such as wind, turbulence, traffic, and/or micro-seismic tremors. Ambient vibration test has two major advantages compared to forced vibration test to obtain dynamic characteristics of large civil engineering structures:

- One is that no expensive and heavy excitation devices are required and therefore easy and economic to implement.
- The other advantage is that all (or part) of measurement degrees of freedom can be used as references.

The identification algorithm used for **Operational Modal Analysis** must so be MIMO. The closed-spaced or even repeated modes can easily be handled.

### OROS Modal 2

**Modern and user-friendly software with specific modules:**

- **Geometry building**
- **Operating Deflection Shape in time and frequency domain**
- **Modal Indicator functions**
- **MIMO identifications methods for EMA & OMA**
- **Modal Validation tools (MAC)**

## Description

Ambient response measurements of a well-known Z24 bridge are applied as a case study for operational modal identification using Frequency Spatial Domain Decomposition (FSDD) technique, implemented in OROS Modal 2. Z24 bridge is an old Swiss bridge over passing the national highway between Bern and Zurich. It is a traditional pre-stressed concrete box girder bridge with main span of 30m and two side spans of 14m, and supported by 4 piers clamped into the girder.

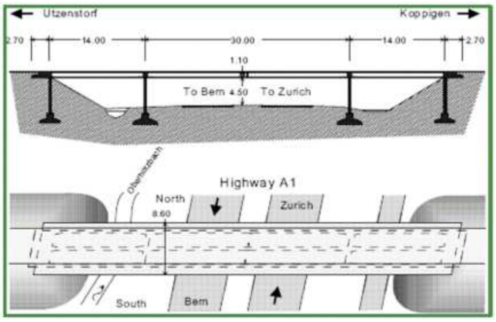


***Figure 1****: Z-24 bridge*

## Analysis procedure

OMA was conducted using response measurements subject to traffic excitation. Data was obtained from 9 accelerometers sets: 8 with 33 channels and 1 with 27 channels. Three references sensors were adopted including one unidirectional and one 3D sensor.

In the FSDD technique, the Power Spectral Density (PSD) matrix is formed at first from ambient response measurements. In a second time, the PSD matrix is decomposed at each frequency line via Singular Value Decomposition (SVD). SVD has a powerful property: capability to separate noisy data to disturbance caused by unmodeled dynamics and measurement noise.

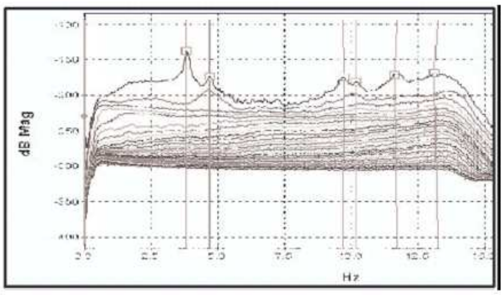


***Figure 2****: MIF of the Z-24 bridge*

Singular value plot, which acts as model indication function (MIF) shown in figure 2, is used to determine the modes. The peaks of singular value plot indicate the existence of structural modes. The singular vector corresponding to the local maximum singular value is unscalled mode shape. It is exactly true if the excitation process the vicinity of modal frequency is white noise. One of the major advantages of SFDD technique is that close-spaced modes, even repeated modes can be dealt with without any difficulty. Only approximation is that orthogonality of the mode shapes is assumed.
In this case, one can see, on the MIF, that 6 modes in the frequency rang of interest are well separated from noisy measurements.

Enhanced Power Spectral Density is then computed making use of 6 singular vectors corresponding to the 6 peak spectral lines as modal filters.

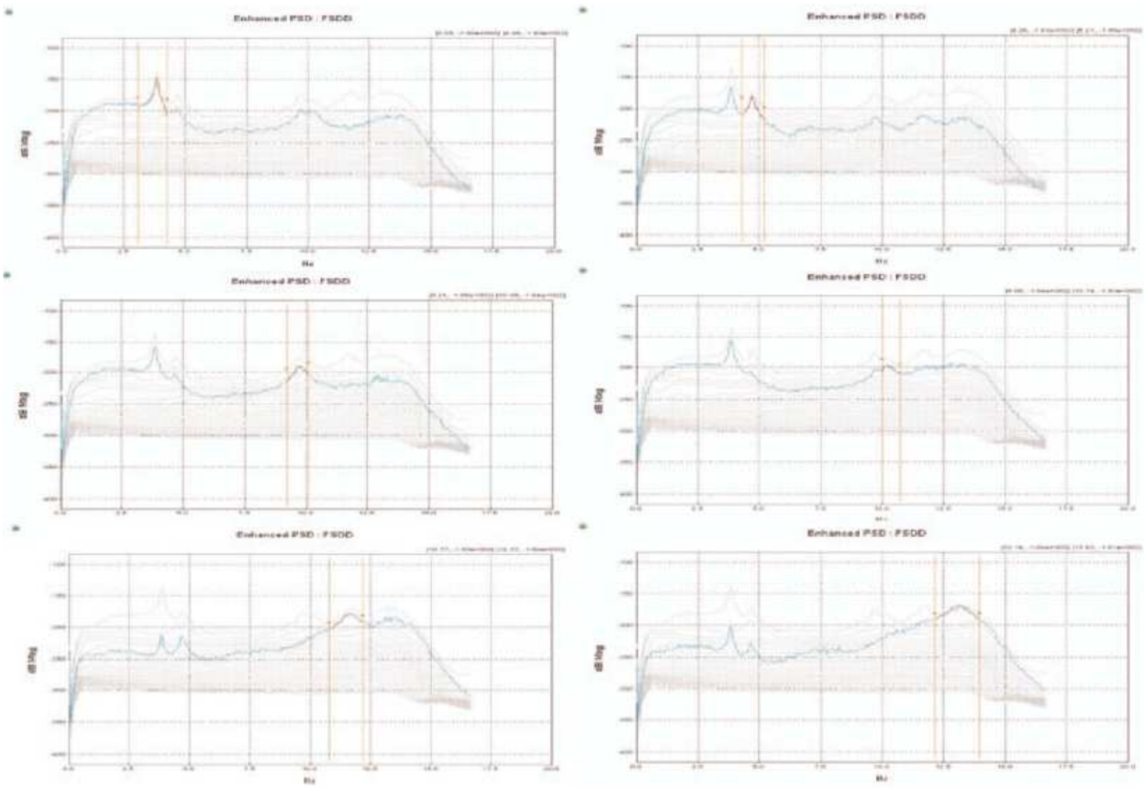


***Figure 3**: Enhanced PDS and curve-fitting on the Z-24 bridge*

Finally, shapes of the 6 determined modes can be visualized:

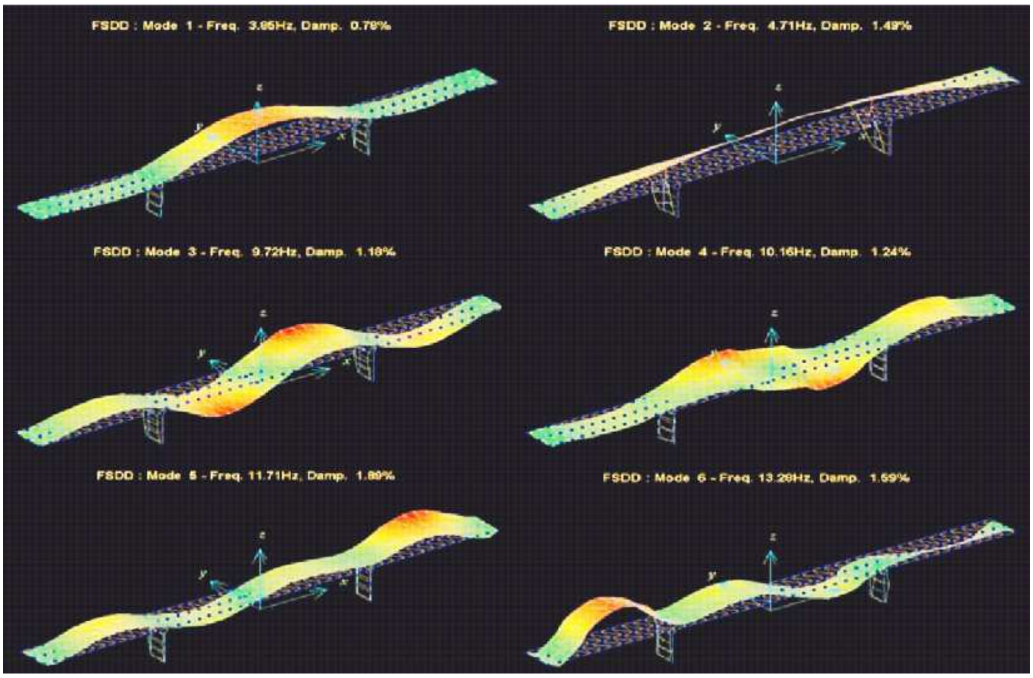


***Figure 4**: FSDD-identified mode shapes of the Z24 Bridge*

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